THE GLASS INDUSTRY

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A. C. S. HOLDS 41st ANNUAL MEETING

The 41st annual meeting of the American Ceramic Society, which was held in Chicago, April 16-22, was notable not only for the fine quality of the papers read but also for the opportunities which it gave glassmen to renew old friendships and create new acquaintances. Abstracts of papers and candid camera "shots" of members of the Glass Division at work and at play are presented.

The sessions of the Glass Division at the Chicago meeting of the American Ceramic Society occupied two full days, packed with the presentation of technical papers and reports indicating lively progress in all phases of glass technology.

Recognition by Dr. Purdy and his staff of the size and activity of the Glass Division took the form of assigning to it the North Ball Room of the Stevens. The size of the room made necessary a public-address system, and a number of members found themselves required to develop a microphone manner for the first time. Also, the scattered seating of the members in the spacious room detracted from the informality and intimacy of discussion that has often been one of the enjoyable features of this meeting. However, Chairman Roche maintained perfect order and allowed no delays, and the Purdy Police, by keeping out casual visitors, reduced to a minimum the confusion of comings and goings from the noisy greeting gallery on registration corridor just outside. Another helpful feature was the gigantic projection screen, upon which the capable students from Illinois showed the slides so well that the illustrating was better than ever.

Twenty-eight papers are a good many. If all the speakers had followed the example set by the more experienced; that is, if they had confined their remarks to the salient points only and allowed the projected pictures and charts to speak for themselves, and left details to be learned by subsequent reading of the printed papers, much more time could have been spared for discussion. However, Dr. Preston had sent his regrets; and much of the material was of the well-organized sort, obviously accurate as to facts, that does not invite disputation.

As a "success" story of an unusual sort, Professor Silverman's biography of Frederick Carder brought out the idealism of this creative artist, and the combination of circumstances that led to the production of Steuben glassware. Illustrations of some of his masterpieces by slides, and a movie of Mr. Carder on shipboard, added realism and interest to the story of our greatest glassmaker.

John Dalton—if his ghost could pass the P-man at the door—would be delighted to see atoms tied into the random lattices that are becoming such real and important concepts to glassmen, under the able tutelage of Dr. Warren of M.I.T. These beautifully interpreted x-ray studies, in addition to confirming ideas as to valence, non-crystalline structure, and absence of molecular compounds in glasses, are now offering plausible explanations as to softening temperatures and expansibilities. Warren's "road maps," with the atoms strung together like towns with one, two, three, or four highways apiece, are now actual two-dimensional pictures to us, of the five-structure of glasses. The next step must be a three-dimensional, stereoscopic view.

H. R. Lillie, Ph.D (doctor of phiscosity), of Corning, discouraged the idea that viscosity curves, by showing dips at strategic points, indicate the presence of compounds in soda-silica glasses. This interpretation by E. Preston is not confirmed; first, because careful measurements of viscosities plot into smooth curves, and secondly, because dips or minima need not indicate compounds. Support of these views was added by George W. Morey.

Clever analyses of deformations of potash-silica glasses in the annealing range, covering elastic (or temporary) stretching, and viscous flow, were given by N. W. Taylor, of Penn State. The flatter viscosity curves of the potash glasses as compared with soda glasses explain their favorable working properties or "sweetness" by supplying satisfactory large words; now we need some technical language to say why potash-bearing goblets make better bells.

The paper of Hans Thurnauer, of American Lava Corp., presented data on glass as a high-temperature dielectric, of particular interest to electrical engineers and makers of insulators.

When a steel ball tunks the middle of a pane of glass, and the cracks run six inches to the edge of the pane, in a ten-thousandth of a second, the fracture is definitely "toot sweet." Photographing such cracks enroute, and timing the interval between the glow and the exposure, are no jobs for camera shutters and stop-watches. The brilliant work by Edgerton and Barstow, M.I.T., made use of sparks lasting one millionth of a second, with an "afterglow" of perhaps five millionths, together with an oscillograph record. Their results check recent German work, with an indicated speed of fracture propagation of 5,040 feet per second. This is less than one-third the speed of sound in glass; hence, vibration often set up return cracks coming in from the edges of the panes.

(*Continued on page* 170)

GLASSMEN AT PLAY

1-2-3. Reception Row, where ceramists gath by twos and threes to discuss the state of nation. J. C. Hostetter, S. R. Scholes, and B. Sosman are prominent among those pres

4. The Rukus, held Tuesday night in the Ce Ball Room.

5. The Ceramic Camera Club organizes. (L to right) Mrs. H. Blair Bartlett, E. L. Hettin V. H. Remington, J. Earl Frazier, I. W. Schi inger, J. M. McKinley, W. A. Kelley, R Purdy, Mrs. Purdy, J. C. Hostetter, W. R. K A. N. Finn, and R. W. Wampler.

6. President and Mrs. A. I. Andrews entert

7. C. J. Peters assisted by K. E. Peiler dem strates the insolubility of glass in the pres of C_2H_5OH.

8. Reception of visiting ceramists. Mary R cliffe has just made a five dollar sales talk, this is the pay off.

9. Round Table Discussion, by B. E. War C. D. Spencer, and Murray Scott.

10. The Colonel himself.

11. F. E. Barstow and V. J. Duplan in con sation with F. W. Adams. (Look for new provements in boiler equipment at M.I.T. Mellon Institute this fall.)

CHICAGO MEETING

Francis Flint and Mrs. L. C. Roche, the mer demonstrating how he makes 'em eat of his hand—and like it.

The Pause that Refreshes, including (left right), K. E. Peiler, John Hostetter, G. W. rey, Dr. and Mrs. Hostetter.

A bit of local color: W. F. Wenning and H. Kohne of New Brighton, Pa.

One of our guests from England, Mr. nk Russell (right), drags a Dunhill while n Forter (left) refuses a furnace order.

Annual Dinner. Gentlemen present: E. rd Tilletson, Donald E. Sharp, T. Wardley, R. Lillie, and K. E. Peiler.

Old South again. E. L. Bohn, A. W. dge, G. P. Cole, and R. W. Knauft.

(Left to right), Walter Emerson, Lee Bar- ger, E. H. Fritz, Arthur Wells, Mrs. Wells, Anderson, V. V. Kelsey, Mrs. Kelsey, Mrs. Affee.

Chairman L. C. Roche and Mrs. Roche ow a party. (Left to right), J. C. Keaney, s. Roche, Alger, Mrs. Keaney, W. R. ster, Mrs. Alger, L. C. Roche, Mrs. Lester.

21. Mob scene in the corridor, waiting for morning divisional meetings to begin.

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The circular pattern of the ends of the radiating cracks showed equal velocity in all directions from the point of impact.

When a diamond is ground to form a tiny tool with a pyramidal face, and this tool is suitably loaded, it may be pushed into the polished surface of glass or other hard material, forming a smooth, unshattered indentation. The area of this indentation is so very small that the load amounts to 500,000 lb. per sq. in. Peters and Knoop, Bureau of Standards, would be the last to attempt to define "hardness," but their series of values for "resistance to indentation" follow the same order as Mohs' scale for the same materials.

But these new numbers, obtained by: $H = \frac{W}{A}$, where W = load in Kg., and A = area of dent in sq. mm., range from about 40 for gypsum to 8,200 for diamond. Glasses suffer depressions about 250 microns long and 25 microns wide under loads of 0.5 to 2.0 Kg., to give a range of values between 190 (below annealed steel) to 500 (just over fused silica) as a kg./mm.^{2} measure of hardness—check!—resistance to indentation. A beautiful job, gentlemen!

W. B. Silverman, of Owens-Illinois, has brought alumina into the soda-lime-silica phase-rule diagram, finding quantitatively how it lowers the liquidus temperatures. Also, he finds that, when glasses in which Al_2O_3 goes in for CaO do devitrify, wollastonite is primary phase instead of devitrite down, to rather low CaO contents. This explains somewhat the scarcity of devitrite stones in commercial glasses.

Polite disagreement appeared between M. B. Vilensky, of Owens-Corning Fiberglas, and Webster and Lyle, of Hartford-Empire, on methods of glass analysis. W. & L. take a number of samples, run off bases, boron oxide, and sulfur trioxide, and get silica by difference. Disdaining this open-field running, Vilensky uses a power play, evaporating for silica in $HClO_4$ solution in a trick-top-radiation device; and he gets a quick, clean separation, followed by one-by-one dropping out of other constituents. Same score.

Plutonic methods, reported by G. W. Morey, seem to be making these geophysicists about as conversant with what goes on in the bowels of the earth as though they had been there; better able to report, anyhow. Simple silicates can scarcely be blamed for melting twice as easily, under a few hundred atmospheres of steam pressure. The apparatus is gorgeous.

"An" Finn made a finished exposition of the work of Hubbard, Hamilton, and himself at the Bureau, on solubility of glass electrodes. The depth of attack (or extent of occasional swelling) was cleverly measured by the interferometer. This work solves the problem of voltage departures in the use of glass electrodes in pH determinations, and furnishes a guide to the selection of more suitable glasses for the construction of electrodes that will not become swell-headed and unreliable.

The walrus and the carpenter would have shed copious tears over the wastes of shining sand exhibited by Dr. McVay in his statriotic report on the splendid deposits that wait for glassmaking in Alabama.

Durability, that problem child of glass research, came in for three papers, any one of which might have kindled a four-alarm fire of discussion. Dilemma: accelerated attack by laboratory methods fails to show how glasses behave in service; service conditions involve relatively geological time. Tooley and Parmelee did some nice work on estimating areas of particles by an empirical method and on the nature and extent of decomposition of glass powder by water. Bacon and Burch reported an extended attempt to correlate powder—and whole-bottle tests, portrayed by a beautiful battery of time-alkali curves; and their high- and low-temperature results wouldn't play ball. Dr. Lundell and his cooperating corps are getting into good agreement on powder tests under standard conditions. It is all a bit discouraging. Good glasses can be told from poor ones, but close specification remains undiscovered, so far as container-contents relations go.

The most definite statements on vanadium as a glass colorant yet to emerge were given by A. E. Badger, University of Illinois, collaborating with Pincus and Weyl, of Penn State. This element responds variously to conditions of composition and melting. Greene, of Rutgers, did not report. Dr. Weyl gave a modern explanation of color changes induced by daylight, and made electrons hop from element to element in a convincing manner.

Those who make materials for glass decoration very appropriately should discover the best conditions for their use. Robertson and Koch, of R. & H., have performed this service, as to firing schedules, and their work seems careful and convincing.

The moot question of how well radiant heat penetrates molten glass approached being answered by R. J. Havens, Univ. of Wisconsin. The neatness and simplicity of Havens' method are to be admired. His work did not go to temperatures above 1100°C., but in the range studied, the hot glass transmitted radiant energy in the important region of wave-length 1.5 microns fully as well as cold glass, although greater absorption was shown farther out in the infra-red. We hope that this work is continued far enough to predict what happens at glass-furnace temperatures.

Plastics are definitely with us—or against us—it's all in the point of view. Dr. F. W. Warner, "Plastics Ave.," G. E. Co., Pittsfield, showed a bewildering variety of these materials and articles made from them, at the G. D. luncheon on Wednesday. "Tough competition," was the brittle remark of a glass man.

Justification of the extended studies of surface tension at the Univ. of Ill. was given by A. E. Badger, who showed how this tight-surface-skin property influences forming operations. C. L. Babcock, of Owens-Illinois, then showed how he lowered a platinum cylinder to touch molten glass and measured the drag of the glass film by a Jolly balance, deriving values for surface tension agreeing well with maximum bubble-pressure data. Calcitic and dolomitic lime glasses were studied. B. can now quite safely predict surface tension from composition.

Developments of floaters, submerged bridges, and skimmers in window-glass tanks to promote homogeneity and eliminate scum were entertainingly traced by R. L. Shute, Univ. of Ill. The bold and effective step of hanging a water-pipe cooler just abaft the drawing chamber ironed out much trouble.

Mold metal has been left altogether too much to casual foundry practice, and it was gratifying to have

these metallurgists at the Univ. of Ill., Bruckner, Kovac, and Wilder, report that an excellent start had been made on the study of cast iron's internal structure, with actual defective molds as specimens. Maps of polished cast-iron surfaces, with crystals recognized for good or ill, must soon be familiar to careful mold makers.

Time flew, and Dr. Silverman was able only to mention the work of Sun Huan Ken, collaborating with Earl Frazier, of Frazier-Simplex, on the design of a Fourcault plant for China. The invasion has made new choice of location and other revisions necessary.

CERAMIC ENGINEERS HOLD ANNUAL MEETING

The annual meeting of the Institute of Ceramic Engineers at Chicago on April 19th was attended by about fifty members and the reports of officers and committees revealed an extraordinary amount of work accomplished in a single year. Highlights of the meeting were the President's annual report, dealing largely with organization problems, and reports by the committees on Ceramic Engineering Education, Professional Status and Development, and Membership and Examinations.

In his retiring address Prof. Greaves-Walker explained the tasks incident to the new organization. For the committees this amounted to an exploratory job, consisting in a number of cases of the study of methods used by the older engineering societies and the adaption of these methods to particular conditions. Prof. Greaves-Walker was able to report the admission of the Institute within recent weeks to the American Engineering Council. Other engineering organizations, such as the Engineer's Council for Professional Development, have cooperated extensively, but the E.C.P.D. has not as yet acted definitely on the Institute's application for membership. The generous attitude of the A.I.M.M.E. in various friendly gestures indicates the maturing of a strong bond between ceramic engineers and this closely-related engineering group. The president also included in his report a summary of the work of W. H. Vaughan's Committee on Professional Licensing. The work of this committee has resulted in legal recognition of ceramic engineering by a considerable number of state boards of engineering examiners.

New officers inducted at the meeting were, *president:* J. L. Carruthers, Dept. of Ceramic Engineering, Ohio State University; *vice-president:* H. G. Wolfram, Porcelain Enamel Mfg. Co; *secretary:* S. J. McDowell, General Ceramics Co.

It was decided that none of those elected to membership in 1938 would be assessed for both 1938 and 1939. Since no announcements of election to the Institute were made until late in November 1938, it was obviously unfair to make an assessment for that year.

Prof. A. S. Watts gave a summarized report for the Membership Committee, stressing the great amount of work and the many problems handled. This key committee is in charge of the Institute's most important function: that of building up a membership of the quality necessary to obtain the society's professional objectives. It was their task to set up criteria for judging applications in the several membership grades. The application of these criteria to the more than 200 applications received entailed an amount of work which will not occur again in any one year. The committee approved the following applications:

For member grade.....21
For associate grade.....55
For junior grade.....27

The total membership of the Institute is now 256.

A stumbling block still present is the uncompleted state of plans for examinations for the member grade, but Prof. Watts' committee has drawn up a set of recommendations which should soon result in a workable program. To date, nearly all of those admitted to member grade were admitted because their possession of an engineer's license was taken as fulfillment of the requirement for the passing of an examination. The committee is moving as quickly as possible toward the completion of a plan for examinations of a satisfactory kind, whether they be oral or written, or a thorough examination of the applicant's record. Until such plans are completed it has been necessary to grant associate membership to some applicants who had applied for the member grade. Of those who are in this group as a result of the immaturity of examination plans, additional patience must apparently be expected. Everyone to whom this situation has been explained agrees that the aim must be the development of a plan which maintains a high membership standard first of all.

The Committee on Ceramic Engineering Education, whose chairman is E. H. Fritz of the Westinghouse Manufacturing Co., uncovered some striking material in a questionnaire survey of employers of ceramic engineers. A great majority of those who replied to the questionnaire considered that personal characteristics were more necessary for the success of an engineer than any detail of his schooling. This report, which will soon be published, includes a summary of employers' views on ceramic engineering curricula.

SCHOLES HONORED

Samuel R. Scholes of Alfred University was elected Dean by the fellows of the American Ceramic Society at their annual meeting at Chicago last month. Edward Schramm was elected Associate Dean; and T. N. McVay, Secretary-Treasurer.

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING MARCH, 1939

Plate Glass: The production of polished plate glass by member companies of the Plate Glass Manufacturers of America during March, 1939, was 11,866,817 sq. ft. as compared to 10,165,401 sq. ft. produced in the preceding month, February, 1939, and 3,802,111 sq. ft. produced in March, 1938. This makes a total of 34,164,748 sq. ft. produced in the first quarter of 1939.

Glass Containers: Production of glass containers during March, 1939, was 4,128,633 gross bringing the 1939 total to 11,099,440 gross. Shipments during March were 3,933,363 gross bringing the 1939 total to 10,722,047 gross.

Window Glass: During March, 1939 the production of window glass was 912,301 boxes which represents 56.1 per cent of industry capacity. As compared with this, March, 1938, production was 528,302 boxes, representing 32.5 per cent of industry capacity.

Nelson W. Taylor

SUMMARY OF PAPERS READ BEFORE THE GLASS DIVISION

• *Summaries of papers Nos.* 1, 4, 19, *and* 23 *are not available at the present writing. Paper No.* 1 *refers to Alexander Silverman's tribute to Frederick Carder. (See* THE GLASS INDUSTRY *for April,* 1939.) *The other papers mentioned were either not delivered or involved discussions which space limitations prevent our presenting.*
—The Editor.

2. X-Ray Study of Boric Oxide-Silica Glass. *By J. Biscoe, C. S. Robinson, Jr., and B. E. Warren, Massachusetts. Institute of Technology.*

Using the same procedure as outlined in his previous papers, Dr. Warren has made X-ray patterns of a series of boric oxide-silica glass and Pyrex-brand chemical resistant glass. The X-ray intensity curves were then given a Fourier analysis to obtain the radial distribution curves.

From these curves the structure of boric oxide-silica glass can be pictured as follows: Each silicon is tetrahedrally surrounded by 4 oxygens at a distance of 1.62A, while each boron is triangularly surrounded by 3 oxygens at a distance of 1.39A. Each oxygen is bonded between 2 cations. The whole pattern follows the random network structure (Fig. 1).

In the case of the Pyrex-brand chemical resistant glass the structure is very similar to that of vitreous silica. This is due to the fact that the bulk of the glass consists of silica (81 per cent) and the other constituents are present in too small amounts to give definite peaks in the distribution curve.

This structure of the boric oxide-silica glass explains the softening of silica by boric oxide additions. Boric oxide when added to a silica glass replaces the fourfold coordinated boron thus making a weaker structure. On this basis the increase in coefficient of thermal expansion with increase in boric-oxide content may also be explained. The addition of boron results in a looser structure which may expand more readily than the more rigidly bonded vitreous silica structure.

3. High-Temperature Viscosities of Soda-Silica Glasses. *By H. R. Lillie, Corning Glass Works.*

E. Preston (J.S.G.T. Vol. XXII, No. 90, page 45, April 1938) in his work on the viscosities of some soda-silica glasses observed marked minima at points corresponding to 34 per cent Na_2O (Na_2O . $2SiO_2$) and 26 per cent Na_2O (Na_2O . $3SiO_2$) (See Fig. 2 below).

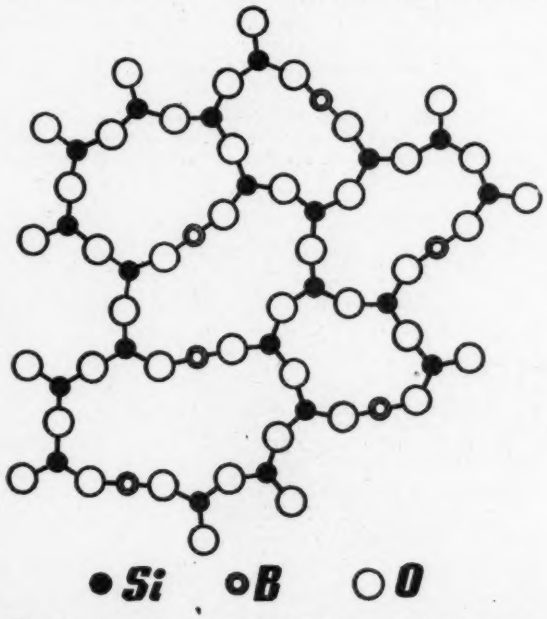


Fig. 1. See paper No. 2 by Robinson and Warren.

Lillie has repeated this work and by a careful study of a series of glass similar in composition to the glasses studied by Preston finds that his data when plotted gives smooth curves for the viscosity-composition isotherms. Additional studies also showed that neither time nor shearing stress has any effect upon the observed viscosities provided that temperature constancy was established.

A very careful study of the deviations of individual points from the smooth curves showed that all irregularities could be accounted for by the experimental error. Lillie concluded that while it cannot positively be proven from the data that no singular points exist at special compositions, it may be contended that such points can be absent or that the extent of their irregularity must be very small.

5. Elastic and Viscous Properties of Several Potash-Silica Glasses in the Annealing Range. *By Nelson W. Taylor and Robert F. Doran, Department of Ceramics, Pennsylvania State College.*

In order to get a better understanding of the factors controlling the viscous and elastic behavior of glass, a series of investigations has been carried out at the Pennsylvania State College during the last few years.

A paper on Soda-Lima-Silica Glass, by Taylor, McNamara, and Sherman was published in the *Journal of the Society of Glass Technology* in 1937. One of the interesting observa-

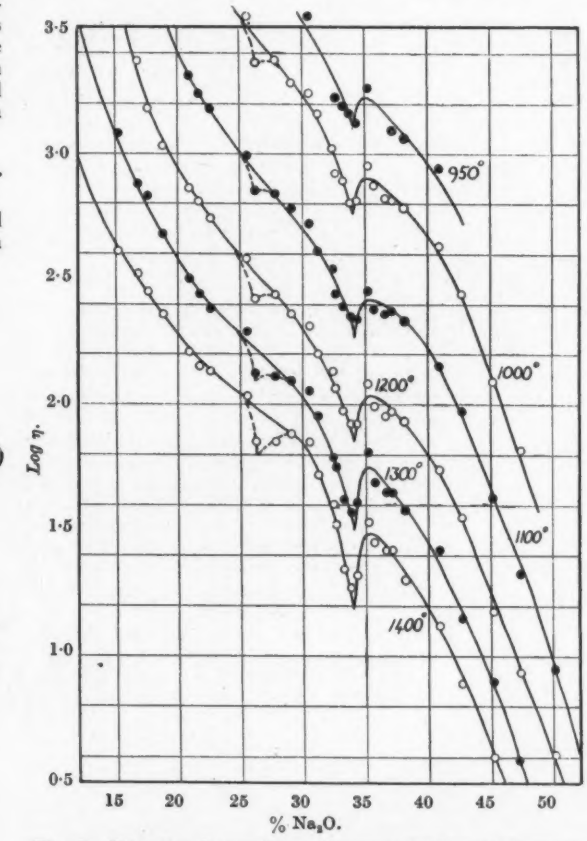


Fig. 2. Viscosity-Composition Curves at Different Temperatures for the Soda-Silica Glasses (after E. Preston), illustrating Lillie's paper.

tions reported was that only the weakest bonds, that is, the sodium-oxygen bonds, appear to be broken during viscous flow. Calcium-oxygen bonds and the silicon-oxygen bonds remained intact so that large clusters of atoms move as a group with respect to one another under shear forces. A subsequent study by Taylor and Dear on Soda-Silica Glasses showed that while the absolute viscosity decreased with increasing amounts of soda, the energy requirement for viscous flow was independent of the amount of soda; that is, it depended only on the strength of the sodium-oxygen bond.

The present investigation on potash glass confirmed these results, and since the potassium ion is of larger size than the sodium ion, the potassium-oxygen bond is weaker and less energy is required to break it. This results in a smaller temperature co-efficient of viscosity, or, in other words, the viscosity of potash-silica glasses is not so sensitive to temperature changes as the viscosity of soda-silica glasses. The former are "sweeter working." The addition of lime had no effect on the temperature co-efficient and shows again that the calcium-oxygen bond is not broken under these conditions.

As regards the elastic phenomenon, the earlier observations on the soda glasses were confirmed with the potash glass in that there is both a sudden and a delayed elastic process. A sudden or very rapid process means that the stretching of the atomic or ionic network takes place with a very small energy requirement. The slow or delayed process is slow because a larger energy requirement is necessary to break some of the bonds in a large atomic complex. Probably several sizes of atomic clusters or aggregates are present. The data have an important bearing on the mechanism of annealing of glass.

A systematic investigation of a variety of glasses will undoubtedly provide us with a complete picture of the annealing process and of the nature of chemical reactions in silicate liquids as affected by their thermal history.

The work is being continued.

6. Dielectric Losses of Glasses at High Frequencies. *By Hans Thurnauer, American Lava Corporation, and A. E. Badger, Dept. of Ceramic Engineering, University of Illinois.*

A study of dielectric losses of various glasses over the frequency range from 100 to 5,000 kc. is being made in an attempt to develop a low loss glass. Measurements of power factor in part of the soda-lime-silica are shown in the figure in the upper right hand corner for a frequency of 100 kc. The heavy lines represent glasses having the same power factor. No correlation between power factor and the equilibrium diagram is evident, the power factor being roughly proportional to the soda content of the glass. (See Fig. 3.)

7. High-Speed Photography of Glass During Fracture. *By H. E. Edgerton and F. E. Barstow, Massachusetts Institute of Technology.*

Using an electric spark lasting less than one millionth second as a light source, cracks in glass have been successfully photographed during their propagation. A steel ball driven against the glass with a spring initiated fracture and simultaneously actuated an adjustable electrical time-delay circuit, which in turn set off the spark at the required instant. By the use of two sparks, the velocity of propagation of cracks in glass was found to be constant and almost exactly 5040 ft. per sec., the same velocity found by Schardin and Struth. In general, the tips of the cracks form a nearly perfect circle at any particular instant, though some individual photographs show non-symmetry.

From the results of this work it was indicated that the cracks were not started by the initial elastic wave that traveled up the rod to the glass, but by the relatively slowly increasing stresses due to geometric distortion of the sample resulting from the blow.

Numerous photographs showing various fracture were given, some of which are presented on the opposite page and at the right. Further work is to be continued through a special fellowship.

8. Resistance of Glass to Indentation. *By Chauncey G. Peters and Fredrick Knoop, National Bureau of Standards.*

In the first attempts to develop a method for making quantitative measurements of the hardness of crystals and glass, clean lines were cut with diamond tools ground to perfect points and edges. It was found that the tools wore rapidly, making the cost of the method prohibitive. Indentation tools of the ball, cone and square-based pyramid types, such as are commonly used on metals, were tried; but these shattered the glass or crystal even under light loads.

An indentation tool consisting of a diamond ground in the

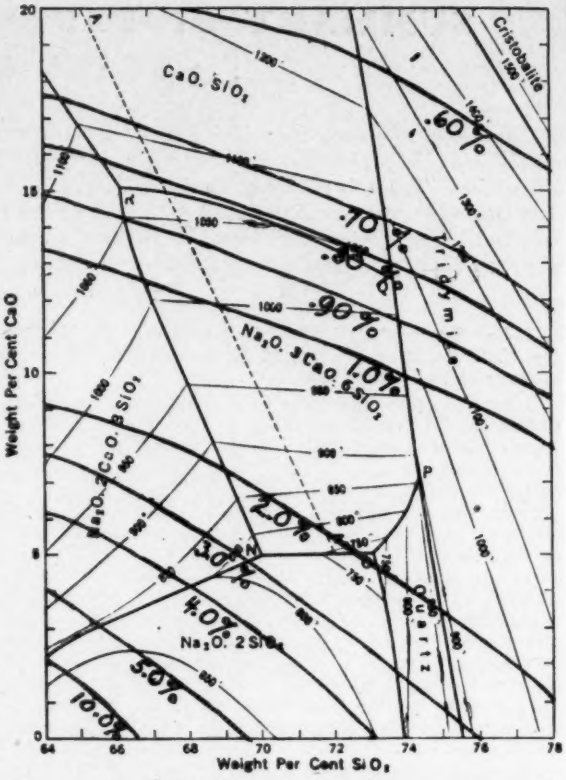
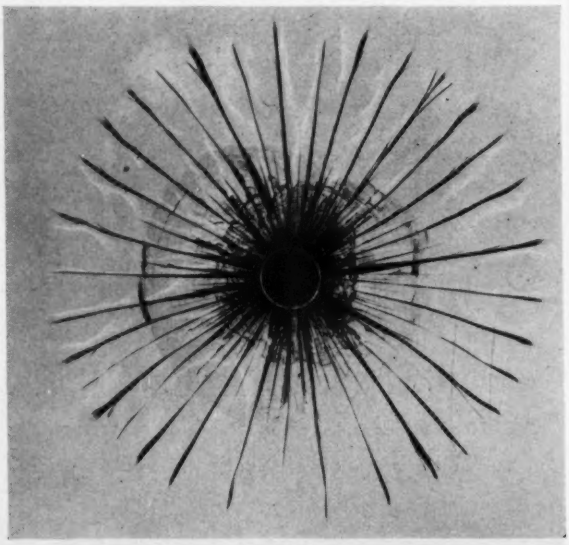
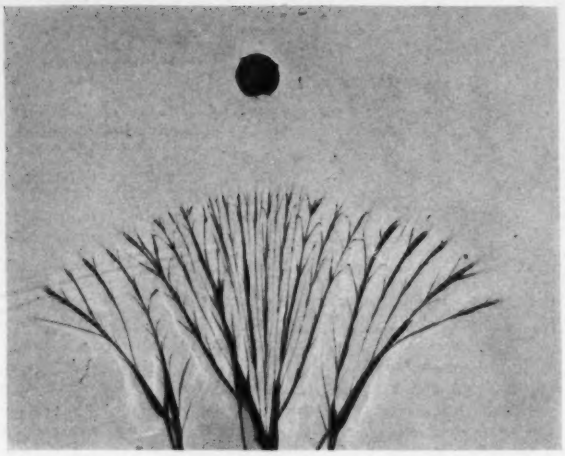


Fig. 3. Power factor (%) at 100 KC superimposed on the portion of the Ternary System, Na_2O-CaO-SiO_2, directly applicable to glass technology. The weight per cent SiO_2 is indicated along the horizontal axis; weight per cent CaO along the vertical axis; weight per cent Na_2O is obtained by subtracting the sum of CaO and SiO_2 from 100. —Thurnauer and Badger.

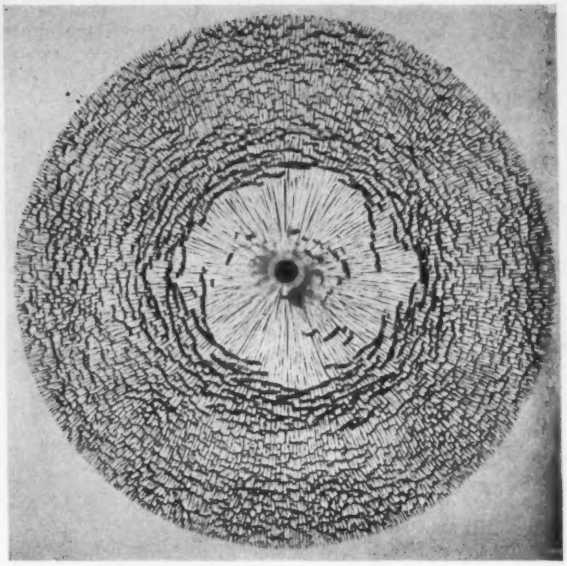
This photograph shows the development of cracks in annealed plate glass 4″ by 5″ by ¼″. Fracture was initiated by a blow at the dark spot in the center.—Edgerton and Barstow.





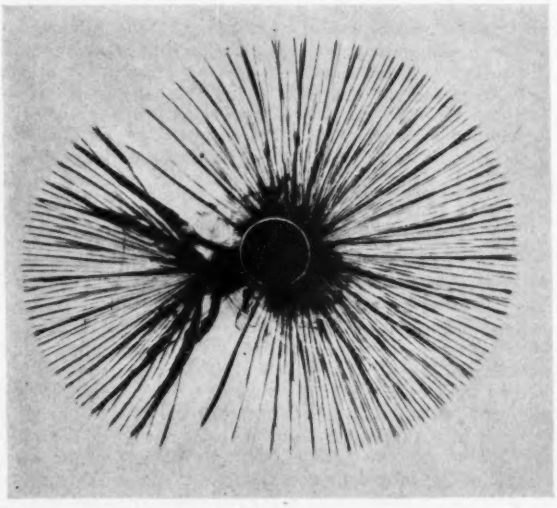
Although the glass was struck at the center, in this particular case cracks may be seen to progress from the edge. —Edgerton and Barstow.

Here the crack origin is displaced slightly from the point of impact. The origin appears to be a line rather than a point.—Edgerton and Barstow.

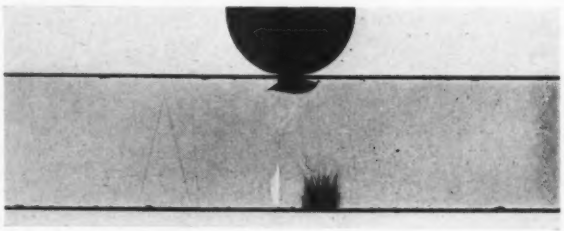


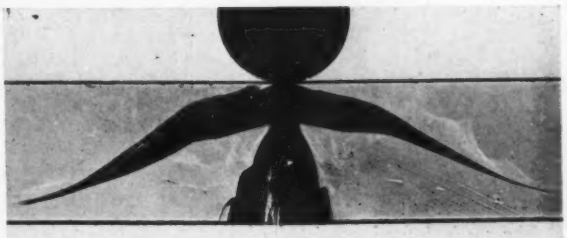
This photograph shows the development of cracks in a 12″ by 12″ tempered glass plate. The radial velocity of the cracks in tempered glass is the same as that in annealed plate, namely, 5,000 ft. per second.—Edgerton and Barstow.

In this unusual case the original crack was probably linear with forking occurring sooner on one end than on the other.—Edgerton and Barstow.



These photographs show a profile or edge view of the growth of a percussion cone in a 1-cm.-square glass rod. Cracks start opposite the point of impact. Because of the physical dimensions of the rod, no radial cracks appear. —Edgerton and Barstow.





• *The photographs on this page and at the left showing the development of cracks in glass were taken using an exposure of less than one-millionth of a second. Fracture was initiated by a 3/8-inch steel ball in the end of a rod driven against the plate by a heavy spring. The black spot visible at the center of all the photographs is not a part of the cracks but rather a hole in the film through which the steel ball protruded. The radial velocity of all the cracks was found to be almost exactly* 5,000 *ft. per second, agreeing with the results obtained by Schardin and Struth, in Germany.—The Editor.*

form of an elongated four sided pyramid was then developed. Tools having included angles between the opposite edges of 100° and 170° to 135° and 175° were investigated and one with an indenter of 130° and 172.5° was selected as being the most suitable for this work. (See illustration in upper right hand corner.)

A machine was also designed and constructed for the purpose of applying loads from 25 grams to 4 Kg. With this equipment clear, unshattered indentations were obtained in glass with applied loads of 1 to 4 Kg. The base of the indentation is diamond shaped, having a length seven times the width. From a single measurement of the length of the indentation and the known angles of the indenter, the area of the indentation under load is obtained. The indentation number is defined as $H = W/A$ where W is the load in Kg and A is the base or projected area in sq. mm. of the indentation while the load is being applied.

From measurements of the width and length of the indentation after the indenter is removed, the recovered area is obtained. The ratio of the recovered to the unrecovered area, R, affords an estimate of the elastic deformation of the material.

The equipment and method were found to be equally applicable to other materials such as metals, porcelain and thin-plated and treated surface layers.

Numbers obtained by this method place elastic and ductile materials on a single rational scale. Typical data obtained are given in Table I while the relation between "H" and the Mohs scale is given in Table II.

TABLE I

Optical Glasses	H	R
90% P60	188	91
Very Dense Flint	313	80
Dense Flint	339	80
Dense Flint	344	81
Medium Flint	357	79
Medium Flint	348	78
Barium Crown	385	80
Barium Crown	392	80
Light Barium Crown	419	79
Light Barium Crown	423	79
Boro Silicate Crown	472	78
Boro Silicate Crown	472	77
Fused Quartz	475	65
Bottle Glasses		
1	434	87
SA	436	82
OA	436	82

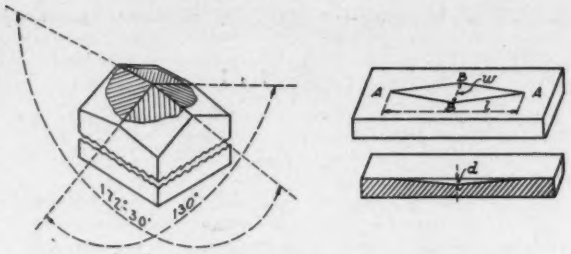
TABLE II—MOHS SCALE

		H
2	Gypsum	32
3	Calcite	135
4	Fluorite Clear	163
	Fluorite Milky	180
	Rockwell 25	271
5	Apatite I axis	360
5	Apatite II axis	430
6	Albite	490
6	Orthoclase	560
7	Quartz II axis	710
	Quartz I axis	790
	Rockwell 66	780
8	Topaz	1250
9	Alundum	1655
10	Silicon Carbide	2130
11	Boron Carbide	2265
12	Diamond	8200

9. Effect of Alumina on Devitrification of Soda-Lime Silica Glasses. *By W. B. Silverman, Owens-Illinois Glass Co.*

Using a series of glasses ranging in composition from 11 to 19 per cent Na_2O, 6 to 18 per cent CaO, 59 to 79 per cent SiO_2 and 0 to 8 per cent Al_2O_3 the effect of the substitution of Al_2O_3 for Na_2O, CaO, and SiO_2 on both the liquidus temperature and phase relations was investigated.

The method used consisted of heat treating samples of



powdered glass in a boat placed in an electric furnace having a temperature gradient of 100°F per inch. After treating the glass the temperatures along the boat were measured with a probing thermocouple. The glass sample after removal from the furnace was made into a thin section and examined under the microscope for the point at which devitrification ceased. The devitrification products were also determined.

From the results obtained by over a hundred determinations, phase rule diagrams were drawn and the effect of the alumina substitution determined. In glasses of low lime content the substitution of Al_2O_3 for CaO permits wollastonite to be the primary phase. With increasing Al_2O_3 the $1 \cdot 3 \cdot 6 - CaO \cdot SiO_2$ boundary shifts to lower CaO contents and the decomposition of the $1 \cdot 3 \cdot 6$ compound takes place at lower temperatures. In cases where tridymite is the primary phase, replacement of SiO_2 by Al_2O_3 causes a lowering of the liquidus temperature.

10. Short Methods for Routine Glass Analysis. *By P. A. Webster and A. K. Lyle, Hartford Empire Co.*

While rapid methods for the determination of the various individual constituents of glasses have been available to the glass analyst for several years, no attempt has been made to work such methods into a systematic procedure capable of producing a complete glass analysis in a minimum of time.

The authors discussed several different plans, each suitable for a different condition, in which rapid methods such as the hydrofluoric-perchloric acid evaporation, volumetric methods for alumina, lime and magnesia, triple acetate method for sodium, the Hicks method for potassium and the partition method for boron were incorporated.

Each of the several plans were tested on the standard glass samples and very good agreement with the accepted analysis obtained. It was found that the accuracy of the individual methods and the complete procedures was such that the silica content of the glass could be fairly accurately obtained by difference methods.

11. Notes on Chemical Analysis of Glass. *By M. B. Vilensky, Owens-Corning Fiberglas Corp., Newark, Ohio.*

The old, tedious method of dehydration of silica is replaced with a new, short method. The dehydrating agent used is $HClO_4$ in place of HCl. The evaporation is performed in 1 to 2 hours by employing a specially designed platinum radiator. The complete chemical analysis of glass is made in a very short time. All ingredients of the glass are determined, one after another, by employing the same sample of the material. The alkali contents are determined on a separate sample. Many samples of different glasses have been analyzed with satisfactory results, which are tabulated.

12. Silicate-Water Systems. *By George W. Morey, Geophysical Laboratory, Washington, D. C.*

The study of the effect of water under high pressure in lowering the melting points of silicate is important to both the glass technologist and to the geophysicist. Dr. Morey presented a short progress report on the work now being conducted in this field by the Geophysical Laboratory.

The special equipment devised by the Geophysical Laboratory for both water and water-carbon dioxide reactions was illustrated and described.

The first results obtained in the study of the water-sodium

disilicate system were given and showed that water dissolved by the molten silicates in quantity, increasing with the pressure, causes a marked lowering of the freezing point of the silicate.

13. Some Notes on the Effect of Solubility of Glass on the Behavior of the Glass Electrode. *By Donald Hubbard, E. H. Hamilton and A. N. Finn, National Bureau of Standards, Washington, D. C.*

The application of an interferometer method, previously used to determine the relative solubility of optical glasses, to a glass commonly used for making glass electrodes, gave results leading to the following conclusions: (1) solubility increases rapidly as the p_H of most solutions increases above 8.5 or 9; (2) at all values below p_H 7 for the solutions investigated (except 10 N H_2SO_4), this glass exhibits a slight swelling; (3) the rate of swelling is repressed in the acid region beyond p_H 2; and (4) at intermediate p_H values, 3.1 to 4.0, the rate of swelling is repressed by high concentrations of magnesium sulfate. Considering these conclusions in connection with the performance of glass electrodes, these regions of marked solubility change correspond to the regions of pronounced voltage departures exhibited by electrodes made from this glass. That the anomalies of the glass electrode are definitely associated with the solubility of the glass has been further demonstrated both by the use of glasses which do not exhibit swelling in the acid range (hence no detectable change of swelling in the "superacid region"), and by measurements made in alkaline solutions, such as aqueous ammonia, in which soluble silicates are not formed. Under these circumstances, the voltage departures are greatly decreased or completely eliminated. For every case investigated, voltage departures of the glass electrode have been found to be accompanied by changes in the solubility of the glass.

14. White Beach Sands of Baldwin County, Alabama. *By R. F. Havell and T. N. McVay.*

As other raw materials such as soda ash, lime and fuel are readily available in Alabama for glass manufacture, the sand deposits of the state have been investigated as sources of glass sand.

The beach sands of Baldwin County, while contaminated with heavy minerals such as kyanite, rutile, tourmaline, staurolite, ilmenite and zircon, readily lend themselves to washing and tabling. After such treatment these sands give iron contents between 0.04 and 0.06 percent.

Flow sheets outlining possible procedures for purifying these sands were also given.

15. Progress Report on the Powder Method of Testing Glass Durability. *By F. V. Tooley and C. W. Parmelee, Department of Ceramic Engineering, University of Illinois.*

Glass durability measurement involves determination of the rate of decomposition, ultimately expressed in terms of the attack per unit surface per unit time. Therefore, we must be concerned with the size of the surface and methods of its measurement or duplication and with the methods of measuring the extent of attack which the glass undergoes. With the purpose of the establishment of a more fundamentally sound basis of durability testing, the following work was done:

(1) A method was developed for the measurement of the surface of irregularly-shaped particles which is independent of chemical composition or surface conditions.

(2) Methods for the determination of sodium (by precipitation and weighing of the triple salt sodium zinc uranyl acetate) and silica (photometrically on the basis of silicomolybdate blue) were tested and found conveniently applicable to the problem of determination of Na and SiO_2 in extracts from durability tests. The point of view has been taken that determination of actual ions in extracts is to be preferred to determination of mass effects of a composite of causes.

(3) Two equal volumes of the same glass collected between the same limiting screens were shown to exhibit measured differences which correlated closely both with chemical attack and positions of their respective distribution curves.

(4) A constant impact apparatus for making possible the expression of the crushing operation in more quantitative terms was designed and constructed.

The evidence in general points to the conclusion that closer specification of the conditions under which the glass grains are prepared is desirable in order to obtain a uniform distribution of particles from sample to sample. Certain recommendations based on this investigation referring to closer specification of details in durability testing by the powder method were referred to the ASTM Committee (C14) on Tentative Methods for their consideration.

It was recommended:

(1) That the ratio of limiting sizes of the grains used in durability tests be made smaller and the range of limiting screens employed be shifted in the direction of larger grains on the curve relating surface per unit volume to surface of a single particle. Each point would serve to reduce the theoretically possible differences in surface per unit volume occasioned by differences in distribution within the range.

(2) That some of the experimental work of the Committee be repeated, determining the Na and SiO_2 directly by methods herein indicated, as well as the alkali by titration. It is believed that with knowledge of the actual ions removed from various glasses tested under different known conditions a more systematic picture of durability, permitting a more satisfactory basis of prediction, will be possible.

(3) That a crushing and sieving procedure be adopted, employing apparatus which will allow the operation to be specified in quantitative terms as nearly as possible. It is recommended that a uniform constant impact apparatus be employed by all investigators in the preparation of the glass particles when the crushing is made by impact and that the following be specified: (a) the total weight of original glass employed in the crushing operation, (b) the general form and number of particles per unit weight (say 40-50 grams) of the glass prior to standard mortar and pestle crushing, (c) the average weight of mortar portion employed in each subsequent cycle of crushing, and the number of such portions per crushing cycle, (d) distance of fall of the impact weight, the weight of the latter, and the number of impacts observed per mortar portion, (e) the number of crushing cycles observed, (f) the weights of the various fractions of glass following each crushing cycle, and (g) the details of the sieving operation. When a given quantity of glass is divided into several portions for sieving, this should be indicated.

16. Effect of Time and Temperature of Test Conditions on Accelerated Chemical Durability Tests Made on Commercial Glass Bottles. *By F. R. Bacon and O. G. Burch, Owens-Illinois Glass Co.*

The chemical resistance of eleven different compositions of glass containers was measured by several different types of accelerated chemical durability tests, both surface and powder methods being used. The bottles used were the 4 oz. "Boston Round" type, having compositions ranging from 14.5 to 16.5 per cent soda, 0.5 to 3.0 per cent alumina and 8.0 to 11.5 per cent lime and magnesia. Both calcite and dolomitic lime glasses were included.

In the powder method the Am. Cer. Soc. Powder Method No. 1 was used both in its original form and in a modified form in which water instead of N/50 acid was used as the attacking medium. The surface methods used included attack by dilute acids, water and alkalis at temperature ranging from 50°C to 121°C.

After analyzing the data obtained on these eleven glasses the authors concluded that: (1) There is no absolute relation between the development of flakes and the amount of alkali leached from the glass in the case of surface tests in which water is used that holds for all compositions of glasses. (2) Glasses having good resistance to acidic solutions do not necessarily show good resistance to alkaline solutions. The reverse is also true. (3) Accelerated tests on glass grains or glass surfaces in which dilute acids are used appear to give results which may be interpreted in terms of the resistance of the glass to the action of acidic solutions at room temperature conditions. (4) Accelerated tests with distilled water actually measure the resistance of

the glass to an alkaline solution the concentration of which increases at different rates for different glasses. (5) The results so far obtained indicate that accelerated tests in which alkaline solutions are used will be difficult to relate to room temperature storage tests in which alkaline solutions are used.

17. Progress Report of the Committee on Chemical Durability of Glass. *By Dr. G. E. F. Lundell, National Bureau of Standards.*

For the past six months Sub-committee III of A.S.T.M. C-14 have been working on various methods of determining the chemical durability of glass. Dr. Lundell reported on the results obtained to date by the various cooperators.

The methods used consisted of (1) powder tests in which acid, water and alkali were used; (2) surface tests in which acid, water and alkalies were used at a temperature of 95°C for 24 hrs.; (3) a modified autoclave test using water.

The results obtained are given in Tables I and II. After an analysis of the data by the committee further work is to be conducted. (See page 180 for Tables.)

18. Vanadium as a Colorant for Glass. *By A. E. Badger, A. G. Pincus, and W. A. Weyl.*

Due both to its high cost and to the fact that the colors that it produces may be more readily obtained with other materials, vanadium is seldom used in glass manufacture. A knowledge of its behavior is necessary however in the study of the mechanism of the coloration of glasses.

The effect of both melting conditions and changes in the composition of the base glass were investigated and the absorption curves of both the glasses and aqueous solutions that were studied were given.

The results obtained in this work showed that the yellowish green tints produced by vanadium are due to a superposition of the green of the trivalent vanadium ion and the yellow of the vanadate ion. The equilibrium between the two seems to be much more dependent upon the melting conditions than upon the composition of the base glass.

20. Mechanical Methods of Mixing Glass in Continuous Tank Furnaces to Avoid Loss from Striae and Scum. *By R. W. Shute, Department of Ceramic Engineering, University of Illinois.*

Experience in the manufacture of glass has demonstrated that a certain amount of glass is produced in the melting process, which has a lower specific gravity and different index of refraction from the main body of glass.

This glass floats on the surface of the molten glass and combines with other impurities such as dissolved clay from the wall blocks to form a light surface layer or scum.

This surface layer is drawn into lines by the movement of the glass from the melting to the working end of the furnace and appears as such in the finished product.

It has been found by experience that the surface layer, if not too heavy, will disappear if mixed with the main body of the glass.

The practice of stirring molten glass to secure homogeneity was carried on by hand in early pot melting and is still done in the case of optical glass. The practice is also carried on in continuous tank furnaces by means of floating clay barriers across the furnace in the case of sheet glass and by bridge walls with submerged openings for furnaces melting glass for containers.

Dissolved clay from the floaters gives rise to "floater lines" which must be broken up by secondary mixing in order to secure any benefit from the primary action of the floaters. The secondary mixing must be carried out by means of a barrier across the cooler part of the furnace composed of some other material than fire clay which will not be dissolved by the glass.

It has been found that this could be successfully accomplished by means of a water cooler supported by the furnace walls and immersed in the glass to a depth of about 1½".

A layer of chilled glass gradually accumulates over the submerged portion of the cooler and a coating composed

(*Continued on page* 180)

***Action*—Honorable Mention—"Pitt-So. Methodist Game," J. Earl Frazier, Frazier-Simplex, Inc., Washington, Pa.**

CAMERA CLUB EXHIBIT NOTABLE

A project of great interest, and one that again indicates the versatility of the members of the American Ceramic Society, got away to an auspicious start during the annual meeting of the society in Chicago, when the new Ceramic Camera Club staged its first exhibit of photographs by A.C.S. members. The work shown proved to be most creditable.

Much credit for the camera club idea and the preparatory work that produced this enjoyable diversion for A.C.S. members and their friends must go to J. M. McKinley and J. Earl Frazier, whose pioneering efforts were ably seconded by other photographic workers. The final success of the exhibit, evidenced by the number of entries and the general interest aroused, called for a formal organization of some sort and this organization was achieved at a Camera Club dinner on Monday evening. The dinner and the following meeting were attended by practically all the exhibitors and by other A.C.S. members interested in photography. Guests included Mr. and Mrs. Ross Purdy and W. A. Kelly, president of the Chicago Camera Club. The worthy secretary of the A.C.S. cheered on the camera enthusiasts, but discerned in the exhibit the lack of a good study of little pigs, a shortcoming that will probably be relieved in the next show. Mr. Kelly, drawing from his long experience in camera club work, gave an able and interesting talk, full of valuable comment.

A constitution and by-laws for the club was presented for discussion and finally approved, setting up a board of governors with five members to handle the administration of club affairs. At a later organization meeting the board elected J. M. McKinley, North American Refractories Co., Cleveland, as chairman and J. Earl Frazier, Frazier-Simplex, Inc., Washington, Pa., as secretary-treasurer. Other members of the governing board for the coming year are E. L. Hettinger, John R. Hostetter, and I. W. Schoeninger. Membership in the club is open to A.C.S. members, practically without restriction, and all the ceramic camera wielders who have not yet joined the organization are urged to at least register with the secretary and secure copies of the constitution and by-laws for their information.

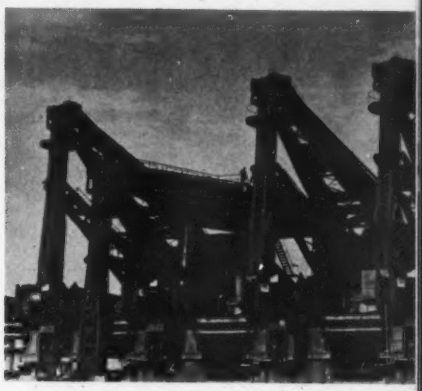
The print exhibition at Chicago was judged by W. C. West and B. D. Frydendall of the Chicago Camera Club. THE GLASS INDUSTRY is privileged to present the winners and runners-up.

A. C. S. CAMERA CLUB AWARDS

Action—1st Prize—"Pigeons," D. H. Rowland, Locke Insulator Corp., Baltimore, Md.

Portrait—Honorable Mention — "Allison," G. B. Remmey, R. C. Remmey Son Co., Philadelphia, Pa.

Industrial — Honorable Mention—"Into th Mold," J. C. Hostetter, Hartford-Empire Co. Hartford, Conn.



Industrial — 1st Prize—"Man on the Mo ster," W. Raymond Kerr, Armstrong Cor Co., Beaver Falls, Pa.

Pictorial — 1st Prize — "The Lonely Pine," Rolland Roup, Globe-Union, Inc., Milwaukee, Wis.

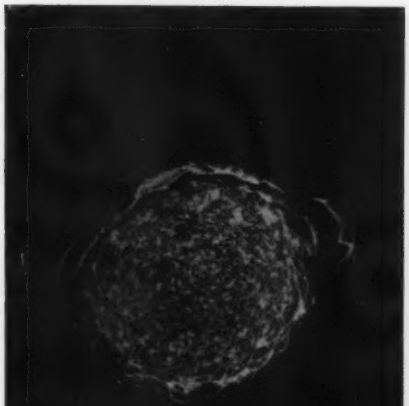
Portrait — 1st Prize— "Patriarch," E. L. Hettinger, Willson Products Co., Reading, Pa.

"Smokestack University," J. C. Hostett Hartford-Empire Co., Hartford, Conn.

Scientific — 1st Prize — "Breaking Glass," E. L. Hettinger, Willson Products Co., Reading, Pa.

Scientific — Honorable Mention — "Sup Tough," E. L. Hettinger, Willson Produ Co., Reading, Pa.

ictorial — Honorable Mention — "Snow Dunes," W. Schoeninger, Globe-Union, Inc., Milwaukee.



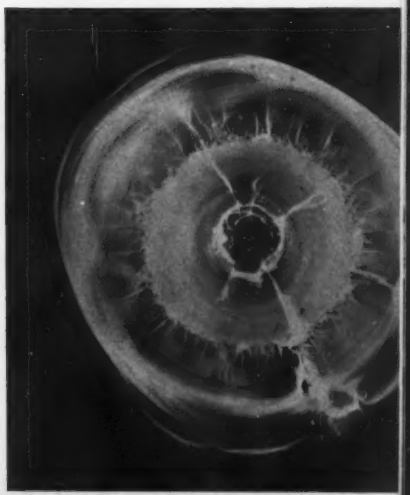


Table 1—Powder methods—Summary of Paper 17 by Lundell
(Expressed as percentage of Na_2O)

Bottle	No. 4	No. 5	No. 6K	No. 6A	No. 7	No. 8	No. 9
	% Na_2O	% Na_2O	% Na_2O	% Na_2O	% Na_2O	%Na_2O	% Na_2O
Method IA.....	0.051 Ca	0.043 F	0.086* B	0.059 E	0.041 B	0.047 B	0.048 E
	.051 B	.044 B	.099 E	.....	.044 F	.049 E	.048 B
	.052 E	.047 E	.102 F	.....	.045 E	.052 F	.052 F
	.052 F	.047 C	.107 C	.....	.046 C	.054 C	.055 C
Ave.....	.052	.045	.103	.059	.044	.051	.051
Ave. deviation.....	.0005	.002	.003	.....	.0015	.0025	.003
ml of titrating soln. — a.d.....	.08	.32	.48	.....	.24	.40	.48
Method IB.....	.040 B	.032 C	.070* B	.043 E	.043 E	.046 E	.049 B
	.043 E	.032 B	.086 F	.....	.043 B	.049 B	.051 E
	.043 C	.035 E	.089 C	.....	.045 C	.050 C	.051 F
	.051* F	.038 F	.089 E	.....	.048 F	.052 F	.053 C
Ave.....	.042	.034	.088	.043	.045	.049	.051
Ave. deviation.....	.0015	.002	.0015	.....	.002	.002	.001
ml of titrating soln. — a. d.....	.24	.32	.24	.....	.32	.32	.16
Method IC.....	.021 F	.015 F	.073 E	.055 B	.040 E	.042 E	.047 E
	.031 E	.020 B	.081 F	.....	.047 B	.051 B	.051 B
	.031 B	.025 E	.....	.....	.051 F	.052 F	.052 F
Ave.....	.028	.020	.077	.055	.046	.048	.050
Ave. deviation.....	.004	.003	.004	.....	.004	.004	.002
ml of titrating soln. — a. d.....	.64	.48	.64	.....	.64	.64	.32

aLetters refer to cooperating laboratories. *Omitted from averages.

Average deviation Method IA for all bottles, 0.002% Na_2O; 64% of values within a.d.
" " " IB " " " .002% Na_2O; 75% " " " a.d.
" " " IC " " " .004% Na_2O; 65% " " " a.d.

Table 2 Surface methods—Summary of Paper 17 by Lundell
(Mg of NaOH per liter)

Bottle No.	Method	Ave.	Min. b	Max. b	Ave. dev. a	Ml of titrating soln. — to a.d.
4	IIA	17.8	14	22	2.6	0.39
5		13.3	11	19	1.5	.22
6K		38.3	35	43.4	2.3	.34
7		18.9	16	24.4	1.7	.25
8		12.3	8.6	16	2.6	.58
9		7.3	3.4	54	2.5	1.5
4	IIB	22.7	19.5	27	2.2	.13
5		17.1	13.6	20	1.9	.11
6K		67.2	57.6	71.1	3.2	.19
6A		32	....	....	....	....
7		35.6	15	44	5.3	.31
8		14.5	11	18.9	2.2	.19
9		13.2	7.2	17	2.4	.57
4	IIC	145.3	74.6	148	2.2	.32
5		105.1	84.2	109.3	3.6	.53
6K		229.7	197.5	235	5.2	.77
6A		105	95	123	12.0	1.8
7		179.8	151.2	185	3.9	.58
8		158	104.3	165	6	1.3
9		141	46.8	158	15	.88
4	IIIB	45.2	36	59.3	8.4	.5
5		30.9	23.7	39	5.2	.3
6K		110.6	93.2	125.4	9.0	.53
6A		52	48	55.9	3.6	.21
7		65.7	48	81.3	10.5	.62
8		55.6	29	78	14.8	1.3
9		32.5	12.6	50	15.8	3.8

bIncludes all values reported.

largely of sodium sulphate forms over the portion exposed to the furnace gases.

It has been found best to remove the cooler from the furnace at periods of 8 to 10 hours, wash the deposit of sodium sulphate off with a stream of water and remove the "cooler skin" of chilled glass by skimming.

The cooler produces the best results when used in glass within the temperature range of 2200°F. to 2450°F. In this range the heat removed from the furnace is not excessive and no seeds or blisters are formed.

The use of this device has made possible higher melting temperatures in the Colburn process where it is employed giving higher production per square foot of melting area, better fuel economy, use of a higher percentage of raw batch, and a greater percentage of higher quality glass.

21. Effect of Firing Schedule on Quality of Glass Color Decorations. *By C. Robertson and D. O. Koch, E. I. du Pont de Nemours and Co., R and H Chemicals Department.*

Using an experimental gas-fired decorating lehr having a 30 ft. tunnel, commercial glassware and colors, a systematic investigation of the effect of the firing schedule on the quality and appearance of vitrifiable glass colors was made. The colors were applied to the ware by the means of the silk screen process. The time schedule and temperature cycles were carefully controlled and a wide variety of schedules used.

An analysis of the data obtained showed that the best elimination of the medium was obtained at a definite and fairly sharp critical temperature. Illustrations showed the appearance of decorations fired at different times and temperatures.

From the results of this practical investigation the authors were able to establish an "ideal" firing schedule that is applicable to full scale leer operation.

22. Absorption of Infra-Red Radiation in Molten Glass. *By R. J. Havens, Department of Physics, University of Wisconsin.*

In attempting to measure the infra red absorption spectrum of molten glass, considerable difficulty was encountered in devising a method of sending the radiation through the molten glass. After considerable experimentation it was found that the best method for accomplishing this was to

send the radiation from a Nerst Glower through the film of glass, the latter being suspended between two platinum wires.

Preliminary results obtained on glass at temperatures of 700°, 950° and 1100°C showed that there is an increase of the absorption with temperature at wave lengths greater than 3.8 μ and a marked increase of the absorption near 2.8 μ.

The paper created a great deal of discussion and it was suggested that further work be done and reported at some future date.

24. Importance of Surface Tension Data to the Glass Man. *By A. E. Badger and C. W. Parmelee, Department of Ceramic Engineering, University of Illinois.*

By the means of practical illustrations Dr. Badger pointed out the various phases of glass manufacture in which the property of surface tension is important.

As one example, it was shown that glass may be drawn into pores and cracks existing in the refractories through surface tension, giving rise to cords produced through the solution of the block. Conversely glass may be rendered more homogeneous through the same property. If the cords in the glass have a lower surface tension than the main body of the glass they tend to expose a large surface to the glass and the diffusion processes and formation of homogeneous glass is favored.

Surface tension is also an important property in glass working methods. The removal of laps and threads by reheating, the elimination of shear marks and the gob shape are all influenced by surface tension. Sheet and tube drawing, fire glazing and polishing, pressing and blowing in figured molds depend upon and are influenced by surface tension.

The importance of surface tension in glass manufacture makes necessary the study of its theoretical side and the collection of data concerning the subject. While much information is already available concerning the effect of the various glass oxides on this property, further research may show how this property may be controlled and put to use. For example, it is known that substances that cause a decrease in surface tension tend to concentrate in the surface. More complete data may show that this fact can be made to produce an improvement in the surfaces of glass.

25. Surface Tension Measurements of Glass by a Modified Dipping Cylinder Method. *By C. L. Babcock, Owens-Illinois Glass Co.*

A modified dipping cylinder surface tension measuring apparatus developed by the author was described. The accuracy of the apparatus and method was checked by the means of liquids having known surface tensions.

Measurements were then made on a series of both calcite and dolomitic lime glasses in the range between 1100 and 1400°C equivalent to viscosities of from log n = 2 to log n = 3.3. The data obtained showed good agreement with the results obtained by the maximum bubble-pressure method used by other investigators on similar composition glasses. It was shown that the temperature coefficient of surface tension is approximately — 0.02 dyne per cm. per °C. In addition the plotting of the data indicated that in this range of composition the surface tension of a glass at a particular temperature may be represented as a linear function of composition.

26. Mechanical Methods of Mixing Glass in Continuous Tank Furnaces to Avoid Loss from Striae and Scum. *By R. L. Shute, Dept. of Ceramic Engineering, University of Illinois.*

A resume of difficulties arising from this source, a description of equipment, methods of combating these defects, and results obtained from use of these methods are presented.

27. Report of Progress in Research on Metallurgy of Cast-Iron Glass Molds at the University of Illinois. *By W. H. Bruckner, L. R. Kovac, and A. B. Wilder: Dept. of Mining and Metallurgy, Univ. of Illinois.*

The Department of Mining and Metallurgical Engineering reports the results of a survey of cast-iron glass molds which failed in service.' The indicated trends for several irons tested to destruction in an accelerated cracking test are reviewed. New methods of studying growth in cast iron are commented upon, and cooperative interest by the glass industry is urged to broaden the scope of the future research program.

Color Changes of Glasses When Exposed to Day Light. *By W. A. Weyl, Department of Ceramics, Pennsyylvania State College.*

Color changes in glasses have been known and described in the literature for more than a hundred years. The most commonly observed color change was the purple developed when glasses containing small amounts of iron and manganese have been exposed to sunlight. The French chemist Pelouze attributed this color change to the formation of trivalent manganese according to the following equation:

$$2\ MnO + Fe_2O_3 \rightarrow Mn_2O_3 + 2\ FeO$$

This explanation still holds true today but would perhaps be better expressed according to modern photo-chemistry as follows:

$$Mn^{++} + h\nu \rightarrow Mn^{+++} + -$$

The divalent manganese ion splits off an electron on absorption of a light quantum and changes to the trivalent state. It acts as a donor for electrons. In order to stabilize the trivalent manganese an acceptor for the split off electron has to be present which in this case is the trivalent iron ion.

$$Fe^{+++} + - \rightarrow Fe^{++}$$

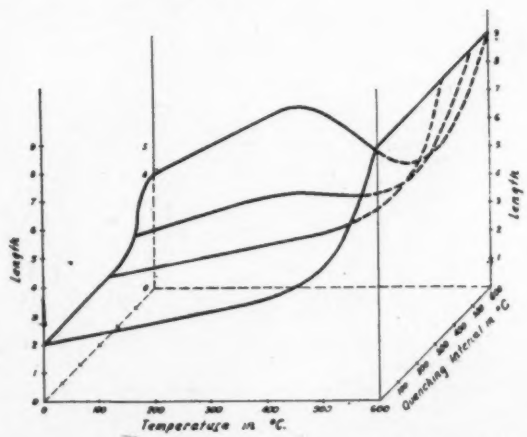
Of course, other elements like arsenic and antimony may act as acceptors too.

As we see a couple of ions have to present for obtaining color changes under the influence of daylight (solarization). As a rule this is also true for color changes under artificial irradiation such as ultra violet light and X-rays. With these radiations which are much richer in energy than sunlight also ions such as oxygen can be made to split off electrons and metal ions such as the alkali metal ions to accept the electron. Consequently care must be taken to distinguish between discoloring effects caused by wavelengths of light shorter than sunlight and those within the range of sunlight when studying solarization by means of artificial light sources. It appears therefore that studies pertaining to solarization by means of artificial light sources are only conclusive when light shorter than the shortest wave lengths present in sunlight is excluded.

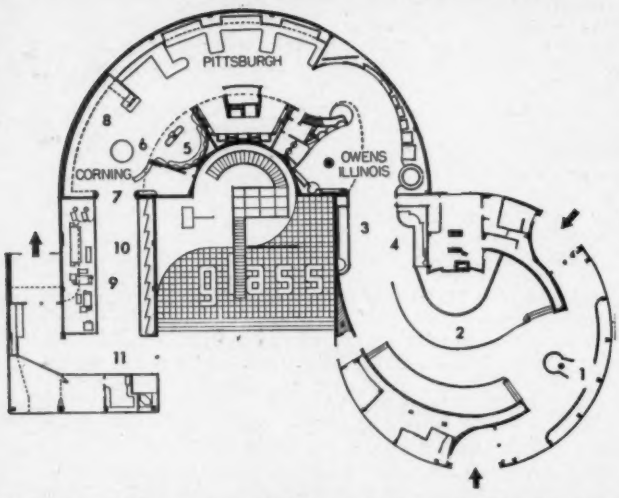
The Thermal History of Glass and Its Effect on Its Physical Properties. *By W. A. Weyl, Department of Ceramics, Pennsylvania State College.*

It is well understood that the properties of ceramic ware such as refractories, whiteware, glazes and enamels must depend on the firing schedule and the rate of cooling. In these cases we have to deal with systems reacting toward a certain equilibrium usually without reaching it under technical conditions. The reactions going on in these materials

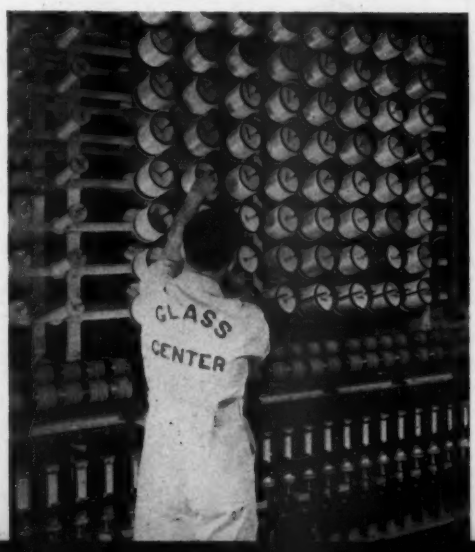
(*Concluded on page* 194)



Space model showing changes in length during reheating of a glass with varying thermal histories.



Plan of the Glass Center. 1. History of glass. 2. Glass blowing. 3. Glass everywhere. 4. Manufacture of glass. 5. Steuben glass. 6. Lamp worker. 7. Telescope disc. 8. Corning Glass products. 9. Fibreglas machine. 10. Properties of glass. 11. Glass in the home.



Flexible fibre glass is spun from marbles, wound on bobbins and woven into fabrics at the Glass Center.

GLASS IN THE WORLD OF TODAY—AND TOMORROW

Symbolic of the increasing role which glass is playing in the world of today—and tomorrow—is the million dollar Glass Center erected at the New York World's Fair through the cooperative effort of the Corning Glass Works, the Owens-Illinois Glass Company and the Pittsburgh Plate Glass Company. The Glass Center is not merely an attempt to glorify the products of the three companies sponsoring it, but rather is an attempt to show that glass—as a material—plays an integral part in the lives of the entire civilized world.

There are such general feature exhibits as a molten glass furnace where the glass is actually blown and worked by master craftsmen and a continuous fiber glass machine making minute strands of glass to be woven into fabrics.

The first thing that will strike your eye as you enter the Center is a series of crystal globes, about 24 inches in diameter, containing carved figures in natural colors depicting the history of glass from its origin down through to the present day. From here, spectators will see a huge wall display clearly showing the elements which go to make up glass. On the opposite wall, three dimensional figures show the countless uses of glass in the industry of today and suggest something of the future.

The Owens-Illinois section consists of exhibits of the products of the various divisions of the company. Miniature talking characters dramatize the merits of glass as a packaging medium and point out various containers. The Insulux division features the use of glass block for the construction of homes, factories and commercial buildings. The glass industry's most recent development, glass in fibrous form, is also shown, particular emphasis being placed on the use of heat, fire and waterproof glass insulating tape for the electrical industry. Another section will show how the Libbey Safedge rim is made for tumblers.

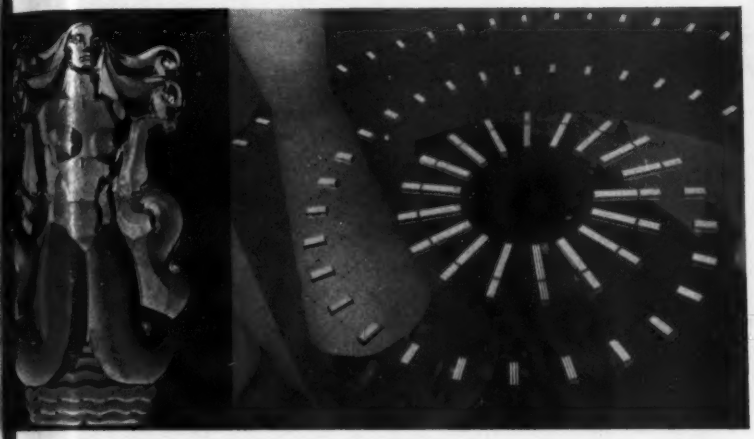
The Pittsburgh Plate Glass section is devoted to an exhibit of modern homes and buildings and to a series of store fronts utilizing various types of glass block, Carrara glass and Pittco moulding. If you'd like a little bit of action, you can press a button and watch a unique break machine try to smash a piece of safety glass. Girls will cut and polish various types of hand mirrors of the type used in ladies' handbags.

An unusually wide range of glass products will be shown in the Corning exhibit. At the entrance will be a 60-inch telescope disk similar to the 200-inch disk at Mt. Palomar, and a 20-inch scale model of 200-inch telescope and the entire south wall is designed to simulate the vastness of the heavens. Application of Corning products in everyday use occupy a prominent position along with a section devoted to scientific apparatus. The Lindbergh-Carrel pump, the Paevex Root and other Corning products in the field of medicine will be shown.

All in all, the Glass Center is something no glass man will want to miss. For it demonstrates to the public that glass is something more than a material for bottles or windows. People here can see glass as it is woven, bent and spun and take home with them a new concept of glass—as the material of tomorrow as well as yesterday and today.

All of the history of glass from the most ancient times down to the present day is presented by a series of sculptured figures displayed in glass retorts.

Expert craftsmen give a demonstration of glass blowing.



Countless people at the preview of the Glass Center amused themselves by getting a worm's eye view of themselves in the mirrored rotunda at the entrance of the building.

A group of glass executives watch the glass blowers in action. Among those present in this scene are H. A. Crowe and J. H. Wright of Libbey Glass, and W. E. Levis, J. P. Levis, Harold Boeschenstein, C. N. Belknap, S. J. McGiveran of Owens-Illinois.

...e world's largest crys-...l statue, titled "Atlan-...a," was created by ...dney Waugh. It is on ...splay in the Glass ...enter.

Two scenes showing the manufacture of fibre glass in the Corning exhibit.

H. S. Wherrett, president, Pittsburgh Plate Glass, Glenn W. Cole, vice-president, Corning Glass Works, and W. E. Levis, president of Owens-Illinois, admire the handiwork of a glass blower.

Featured in Pittsburgh Plate's exhibit are a series of sample store fronts in model form. Shown here is every type of structural glass, including plate, carrara, glass block and art glass panels as well as Pittco moulding.

BAUSCH & LOMB OPENS EXHIBIT

Commemorating the 25th year of optical glass experiments in the United States, the Hall of Optical Science, sponsored by the Bausch & Lomb Optical Company, was opened at the New York Museum of Science and Industry in Radio City on April 20th. Preceding the opening, a lunch was held in honor of William Bausch, vice-president of the company, who unfortunately was unable to be present because of illness.

The Hall of Optical Science is designed to translate the laws of optics into dynamic displays of light, motion and color and is a fascinating spectacle to glass man or layman. By merely pushing buttons or turning knobs, visitors may see how different surfaces reflect, refract or disperse light. Cross sections of such instruments as binoculars and microscopes have been arranged to show the path of light and their mechanical features.

The Hall dramatizes the subject of optical science from three angles: theory, manufacture and application. By merely pressing buttons it is possible to obtain interesting demonstrations of the law of reflection, the law of reflection and refraction from the same surface. Various ramifications of these laws as they apply to binoculars, spotting scopes, microscopes and even to modern eye examination are vividly demonstrated.

The section devoted to optical application traces the evolution of the microscope from the early Jansen 'scope developed about 1590, through to a replica of a microscope built by Edward Bausch in about 1872, down to the most modern type of microscope. Various optical illusions, illuminated microphotographs in color, different kinds of optical instruments are also in this section. The concluding display here includes a turntable of optical parts and a demonstration of fluorescence.

The center feature of the section on optical manufacture shows a glass manufacturing plant. Pots of molten glass are seen as they are taken to the furnaces, then removed, carried to a casting table, poured out and rolled flat. In the foreground are shown the ingredients used in the manufacture of optical glass. An unusual feature of this section is an optical illusion to enable visitors to "try on" different types of eyeglasses to see how they look. The "trying-on" is done simply by turning a knob. There is also depicted twelve eyeglass styles of different periods of history. Another interesting sight is the 44-inch parabolic mirror designed for use in a searchlight and an exhibit demonstrating the reflecting power of this type of mirror. A model of a lens grinding machine demonstrates the grinding and polishing of convex, concave and flat lenses.

While the Hall of Optical Science, which will remain in the Museum of Science and Industry for about one year, is designed primarily to popularize optics, glass men will find it a fascinating exemplification, in miniature, of the delicacy of the science of optics.

TURNER VISIT CANCELLED

Professor W. E. S. Turner of Sheffield, England, who was scheduled to deliver a series of lectures at the Summer Glass Conference of the Massachusetts Institute of Technology has cabled to Professor Norton his inability to fulfill this engagement. Ill health and the necessity of refinancing his work in new and more extensive premises have prevented Professor Turner from visiting America.

HIGH TEST SAFETY GLASS INTRODUCED AT BANQUET

The Franklin Institute of Philadelphia saluted the development of high-test laminated safety plate glass for automobiles at an assembly and dinner in Philadelphia March 31, at which representatives of five companies that collaborated in producing the new product were guests of honor. It was the formal introduction to 325 scientists and industrialists of a super-safety product resulting from six years of concerted research effort and an expenditure of $6,000,000.

The new glass, strong enough to stop a half-pound steel ball traveling at a speed of 56 feet per second, yet, when broken, flexible enough to be rolled up like a rug, was tested before the guests in demonstrations conducted by Dr. Nicol H. Smith, associate director of the Institute in charge of chemistry. According to the manufacturers, the new glass will be available to all car manufacturers at no additional cost in sufficient volume to serve approximately 75 per cent of automobiles manufactured this year.

The companies honored "in accordance with Franklin Institute's policy of recognizing outstanding industrial and scientific contributions to the welfare of mankind" were E. I. du Pont de Nemours & Co., Monsanto Chemical Co., Carbide & Carbon Chemicals Corp., Libbey-Owens-Ford Glass Co., and Pittsburgh Plate Glass Co.

In addition to a telegram of greeting from President Roosevelt, the guests heard addresses by Stewart McDonald, Federal Housing Administrator; Paul G. Hoffman, president of the Automotive Safety Foundation, and Dr. Edward R. Weidlein, director of the Mellon Institute.

Tests have shown that the new safety plate glass is about twice as resistant to impact penetration as the regular cellulose acetate plastic type; at zero, it is five or six times as strong. A passenger trapped in a car equipped with polyvinyl plastic safety glass may force the glass out of its frame more easily and with less danger of injury. Most spectacular of the tests was the illustration of the new glass' efficiency at low temperatures: A sample of cellulose acetate safety plate cooled down to 20 degrees in an icebox on the stage, was completely shattered and pierced when the ball was dropped only 12 feet, while a similarly chilled sample of high-test easily turned aside the steel ball dropped from 28 feet.

Polyvinyl plastic is resistant to moisture, which makes unnecessary the sealing of the edges, and will not separate from the glass. Replacement is a simple matter, since the safety glass may be cut by scoring and cracking, then drawing the glass away from the plastic and slitting the latter with a razor blade. All the participating companies confirmed their experiments with extraordinarily rigid tests covering several years. Samples were subject to ultra-violet arc and natural sunlight for long periods to prove its non-deteriorating properties.

Samples of glass laminated with the new filler were subject to actual tests in automobiles, and to tests for handling, over a wide geographical range embracing different climatic conditions. Laboratory tests included some involving light and water at varying degrees of heat and pressure, including boiling in water for seven hours. Special refrigeration rooms were constructed to test its effectiveness at unusually low temperatures.

ANALYSIS OF STRAINS AND STRESS IN GLASS

II—POLARIZED LIGHT IN STRAINED GLASS

By A. J. MONACK and E. E. BEETON
WESTERN ELECTRIC COMPANY, INC.
VACUUM TUBE SHOP

This, the second article of the series, discusses the action of strained glass on polarized light and shows how colors and dark areas produced in the polariscope are utilized to determine the amount and kind of strain present.—The Editor.

All transparent materials can be classed as isotropic or anistropic, i.e., not isotropic. When an isotropic material is viewed in a polariscope, no color effects are produced, the field of view remaining unchanged because the light travels through the material at the same speed in all directions and the emergent light is unaltered from what it was when it entered. Unstrained glass is an isotropic material, but when glass is strained it becomes anistropic. In anistropic substances all light, except that which traverses the substance parallel to the optic axis, is separated into two rays which do not travel at equal speeds and generally do not follow the same paths, as shown in Fig. 4. Most anistropic substances are crystalline, exceptions being strained glass and some stressed materials, such as organic plastics, stretched rubber, and a few amorphous solids. Anistropic crystals are divided into two classes, uniaxial and biaxial, but since strained glass behaves as a uniaxial crystal, it will not be necessary to discuss the biaxial variety.

The crystal of calcite shown in Fig. 4 is uniaxial and, even if the light incident on the lower surface happens to be plane polarized, it will still be broken up into two rays, an ordinary and an extraordinary, each of which is polarized, as has been shown. In general, therefore, when plane polarized light enters a uniaxial crystal it is broken up into two polarized rays which vibrate in planes at right angles to each other and travel at different velocities, these velocities being inversely proportional to the indices of refraction of the crystal. One of these polarized rays always vibrates in a plane which includes the vertical crystallographic axis (the optic axis), so the other ray must vibrate in a plane perpendicular to the optic axis. There is only one direction in which polarized light can pass through the crystal without being doubly refracted, this direction being parallel to the optic axis; and light entering from any other direction will be doubly refracted into two polarized rays which vibrate at right angles to each other.

These relations are shown in Fig. 10. The optic axis is *cc;* the horizontal axes are *aa* and a′a′. One ray, vibrating parallel to the plane of the axes *aa* and a′a′ as in Fig. 10c, always travels with constant velocity, because the optical properties of the crystal are always uniform in the horizontal plane. This constant-velocity ray is called the ordinary ray (O ray), its index of refraction, N_O, always being constant for a given wavelength of light. But the other ray always vibrates at right angles to the ordinary ray, and in a vertical plane which includes the optic axis *cc.* Furthermore, its velocity varies with the inclination of the incident light to the horizontal plane and, consequently, its index of refraction, N_E, also varies. Because of this queer behavior, the ray is called the extraordinary ray (E ray), and the difference between its index of refraction and that of the ordinary ray will be greatest when the incident light is parallel to the horizontal axes.

The relation between the indices of refraction of the ordinary and extraordinary rays is shown in Fig. 11, in which YY′ represents the optic axis. With the incident light in the direction of YY′, both rays travel with the same velocity; and at right angles to this direction, that is, along the other axis of the ellipse, the extraordinary ray shows its greatest velocity difference relative to the ordinary ray. The velocity difference for light incident at an intermediate angle, Fig. 10b, is represented at a point P, Fig. 11. It can be seen that the velocity of the ordinary ray, represented by the radius of the circle, remains the same regardless of the angle of incidence.

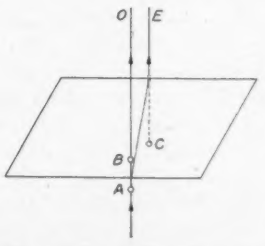
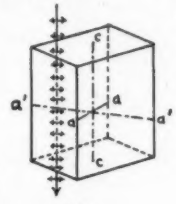


Fig. 4. Double refraction of light into ordinary and extraordinary rays by means of a crystal of calcite. ***(This figure is repeated from the April instalment.)***



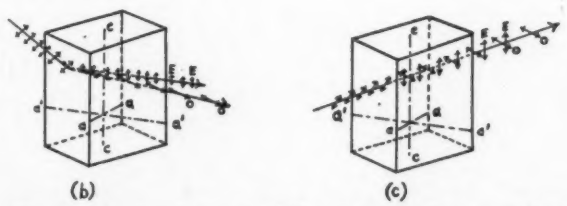


Fig. 10. Action of a uniaxial crystal on a ray of polarized light. (a) Incident ray parallel to optic axis; (b) Incident ray at an angle with horizontal axes; (c) Incident ray parallel to horizontal axes.

Fig. 11. Diagram showing the relationship between velocities and refractive indices of ordinary and extraordinary rays in positive and negative crystals.

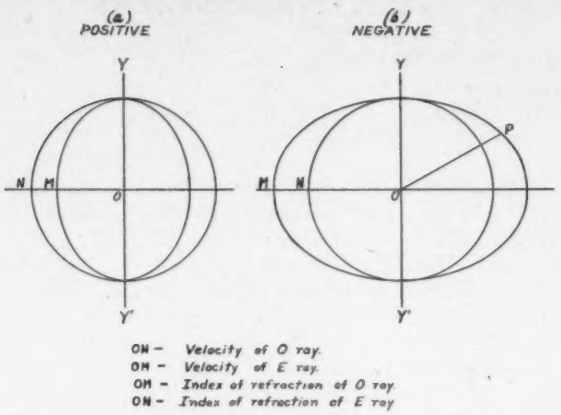


Fig. 11 also furnishes the explanation for the separation of all uniaxial crystals into two classes, called positive and negative. When the velocity of the extraordinary ray (E ray) increases, as the direction of incident light moves gradually from the optic axis, until it becomes a maximum with the incident light normal to the optic axis, the crystal is called negative, Fig. 11b. In this case the sphere, representing the velocity of the ordinary or O ray, is inside the ellipsoid. But when the velocity of the E ray gradually decreases from the optic axis until it reaches a minimum at right angles to the optic axis, the crystal is called positive, as indicated in Fig. 11a, and the ellipsoid is inside the sphere. Or, since the index of refraction is always inversely proportional to the velocity, these two classes may be defined in another way. Thus in negative crystals, in which the E ray travels faster than the O ray, N_O is greater than N_E; in positive crystals, N_E is greater than N_O.

It is now possible to discuss the optical character of strained glass, and a block of glass, as shown in Fig. 12, can be considered. The atoms of the glass, as shown by recent X-ray studies, are randomly arranged, but if compression is applied, the atoms are forced[5] into what may be called a crystalline arrangement and crystalline optical properties result. The E ray then travels faster than the O ray and N_O is greater than N_E. The block of glass has, therefore, become uniaxially negative, in an optical sense, and exhibits the same behavior toward incident light as the crystal described in the preceding paragraph. On the other hand, if tension is applied, the atoms are again forced into a regular or repeating pattern. However, the O ray now travels faster than the E ray, and N_E is greater than N_O. Consequently, the block of glass behaves as a uniaxial positive crystal.

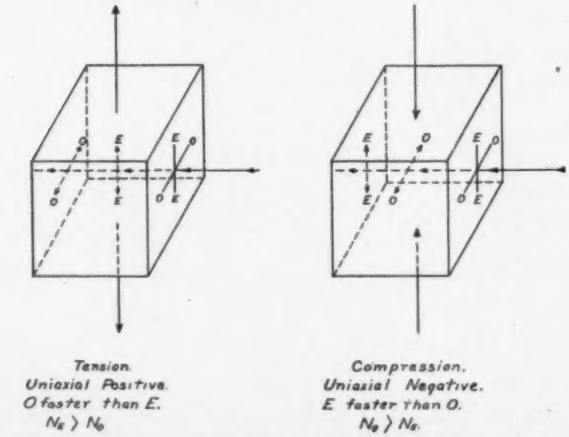


Fig. 12. Passage of polarized light through strained glass, showing the effect of tension and compression.

It must be remembered that any discussion of a uniaxial negative crystal applies also to glass in compression, while the discussion of the uniaxial positive crystal applied to glass in tension. A combination of forces acting on the block of glass would, of course, result in a much more complicated problem and this will be taken up later.

Behavior of Polarized Light in Strained Glass

It is important to realize that when a piece of strained glass is placed between crossed nicols the light is doubly refracted and plane polarized three times. In Fig. 13a a glass plate, instead of a nicol, is used as the polarizer, but this gives the equivalent of a double refraction and a plane polarization. As shown, the ray of light strikes the plate of glass and the reflected ray, vibrating parallel to the plate, enters the strained glass where it is separated into two rays of polarized light. These rays, marked O and E, vibrate at right angles to each other and one travels faster than the other, in accordance with the previous discussion of positive and negative crystals. After leaving the strained glass, these two rays enter the nicol prism, as shown, and each of the two rays is here separated into two other rays. The O ray is broken up into an O′ and an E′ ray; the E ray is broken up into an O″ and an E″ ray. The rays O′ and O″ are totally reflected to the dark wall of the nicol prism, but the E′ and E″ rays pass through the analyzer and, since their vibrations are in the same plane, they interfere or combine with each other.

The plan view, Fig. 13b, shows the relations between the rays which were traced above. PP′ is the direction of vibration of the ray polarized by reflection from the glass plate. When this ray enters the strained glass it is broken up into two rays; O, represented by BB′, and E, represented by AA′. These are at right angles to each other. Let DO represent the vibration of the ray from the polarizing plate. Then GO may be taken to represent the vibration of the O ray in the strained glass, while OF represents the vibration of the E ray. When the O ray reaches the nicol prism it is separated into the ray O′, represented by NO, and the ray E′, represented by LO. When the E ray reaches the nicol prism it is separated into the ray O″, represented by HO, and the ray E″, represented by KO. The rays O′ and O″ (NO and HO) disappear into the wall of the nicol, but the rays E′ and E″ whose vibrations are represented by LO and KO, pass through the analyzer and, being in the same plane and having a fixed phase relation, interfere or combine with each other.

When the vibration directions of the rays in strained

[5]In the stressed state the atoms in planes normal to the strain always have the same separation, but the distance between planes varies according to the kind and magnitude of the applied force. This, however, gives only one component of the optical effect. The other is due to deformation of the atoms.

glass coincide with those of the polarizer and analyzer, if these are crossed, the section appears dark. Such darkness always results when the direction of stress in strained glass is parallel to the vibration direction of either the polarizer or analyzer.

Interference of Light

When two waves travel along the same path and vibrate in the same plane they "interfere" to form a resultant wave whose character depends upon the wave length, the amplitude, and the phase of each component wave. Fig. 14 shows the resultant waves produced by interference of waves with the characteristics indicated.

It was stated in the previous section that the rays which emerge from the analyzer, E′ and E″, interfere or combine with each other, and this requires further explanation. As shown in Fig. 14b, the simple combination of two light waves results in darkness when the phase difference is half a wave-length, but when monochromatic light passes in succession through a polarizer, strained glass, and an analyzer, darkness results when the phase difference is one wave-length or a whole number of wave-lengths.

In Fig. 15a, for example, let PP be the plane of vibration of monochromatic light from the polarizer. When this polarized light enters the section of strained glass HIJK, whose vibration planes are SS′ and RR′, it may be assumed that the vibration of a particle at O, which has its crest at B, is resolved into the components OB′ and OB″. If these waves pass through the strained glass so as to have no difference of phase at emergence, or a phase difference of a whole number of wave-lengths, the wave OB″ will be at its crest B″ when the wave OB′ is at its crest B′. If they acquire a difference of phase of half a wave-length, or any uneven multiple of half a wave-length, the wave OB″ will be at B″ when OB′ is at its trough T.

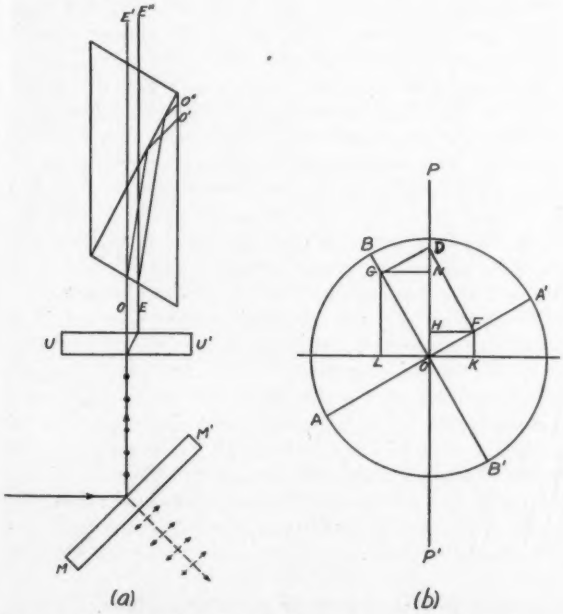


Fig. 13. Strained glass in the polariscope. (a) Diagram showing the paths of the rays through the glass sample and the analyzer. (b) Geometric construction for finding the components of the rays emerging from the analyzer.

Regardless of the phase difference which results from passage through the strained glass, however, when the two waves enter the analyzer, whose vibration plane is AA, each will be resolved into two components, the components in the plane PP being totally reflected and absorbed in the walls of the analyzer, while the others, in the plane AA, pass on through the upper nicol. If the difference of phase is one wave-length the components which will be absorbed may be represented by OC and OC′. The components which pass through the analyzer are shown by OX and OY in Fig. 15b, and their positions will be as indicated if the phase difference is any whole number of wave-lengths. The waves OX and OY are opposite in direction and will destroy each other if monochromatic light is being used. This will result in darkness. But if the difference of phase is half a wave-length, or an uneven multiple of half a wave-length, the wave vibrating in the plane SS′ will be at B″ when the wave vibrating in the plane RR′ is at T. Hence the components of these waves vibrating in the plane AA will be two waves, each OX, of equal amplitude and acting in the same direction. The resultant wave will have double the amplitude and four times the intensity.

Whenever the phase difference is neither a whole number of wave-lengths nor an uneven multiple of half a wave-length, the resultant wave will always have an amplitude varying between the limits given above.

These rules can be used only with monochromatic light and difference of phase (retardation) must be measured in some other unit when white light is used. White light has no definite wave-length, because it consists of waves whose lengths vary from about 380 to 760 millionths of a millimeter, these limits usually being expressed as 380 to 760 millimicrons, or 380 to 760 mμ. Medium values of the wave-lengths of the colors which make up the spectrum are as follows: violet, 410 mμ;

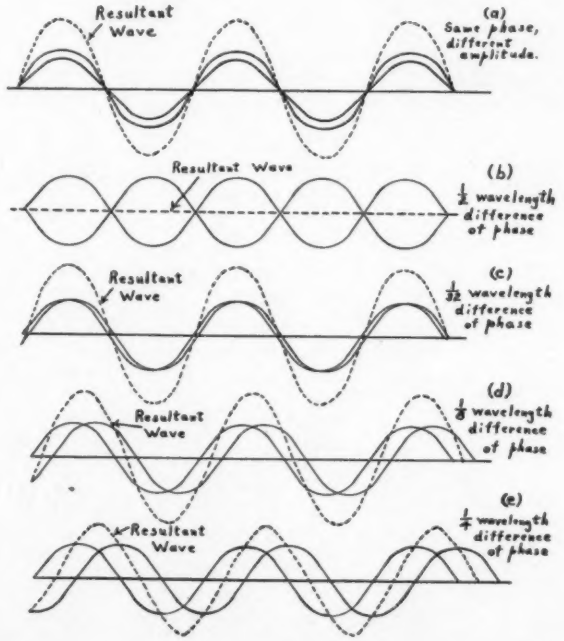


Fig. 14. Resultant waves produced by interference of waves with different characteristics.

blue, 460; green, 510; yellow, 565; orange, 620; and red, 690. It must also be remembered that the intensities at various parts of the spectrum are not the same, being greatest for yellow and least for violet. With these facts in mind it is possible to consider the effects of phase difference on white light. The effect produced is dependent upon the relation of the phase difference to the wave-lengths of all parts of the white light.

This is illustrated in Fig. 16, which shows the values of phase difference for which darkness results with each color of the spectrum taken separately. For instance, with violet monochromatic light darkness results when the difference of phase is one wave-length, λ (410 mμ), when it is 2λ (820 mμ), etc. Similarly for the other colors, darkness results when the phase difference is λ, 2λ, 3λ, etc., in accordance with the explanation of Fig. 15. Since white light is the sum of the colors shown in Fig. 16, this diagram can be used to determine the resultant color for any value of the phase difference. Each component of the white light will behave as if it were present alone and the resultant color can be obtained by noting which colors are near a maximum ($\frac{1}{2}\lambda$) and which have been destroyed (λ, 2λ, 3λ, etc.).

With no difference of phase all parts of white light destroy each other in the analyzing nicol, and the result is darkness. As the phase difference varies from 0 to 260 mμ the effect varies from darkness to white light; at 300 mμ yellow light is produced, since yellow is near its maximum (one-half of a wave-length of yellow) and violet is partly destroyed. Violet is completely destroyed at 400 mμ, and blue and green are weakened. While yellow is past its maximum, it dominates over the red because of its greater relative intensity. For the same reason orange appears at 425 mμ and red at 530 mμ. Violet is produced at 565 mμ, since green, yellow, and orange are nearly destroyed, and red and blue combine to increase the violet. There are slight variations as the phase difference increases, but the order is generally repeated, as shown by Table I. This table is of great importance in connection with strained glass because, as will be shown later, these colors can be used to determine approximately the stress in glass.

TABLE I

PHASE DIFFERENCE AND COLOR WITH WHITE LIGHT

Phase Difference	*Color*
50 mμ	Iron gray
200	Grayish white
300	Yellow
425	Orange
530	Red
565	Violet
640	Blue
740	Green
840	Yellowish green
880	Yellow
945	Orange
1030	Red
1100	Violet
1200	Bluish green
1300	Green
1425	Yellow
1500	Orange

(The colors become paler as the phase difference increases)

In strained glass the interference colors will always be of maximum intensity when the planes of vibration of the rays in the glass are at 45 degrees to the planes of vibration of the polarizer and analyzer. Darkness results when the planes of vibration of the rays in the glass are parallel to the vibration planes of the polarizer and analyzer. The reason for this is plain from the previous discussion of crossed nicols.

The Sensitive Tint Plate

The sensitive tint plate, already mentioned, is an extremely useful accessory for use with the polariscope and makes important deductions concerning the kind and degree of strain in glass possible. The tint plate is a plate of gypsum or quartz (though other minerals may be used, e.g., mica) cut to such a thickness that it produces a violet interference color, called the "first order red," when placed properly between crossed nicols. This thickness of the plate is of the order of 0.05 millimeters and the mineral is cemented between glass plates for protection. Such a tint plate is similar to the selenite or gypsum plates used with petrographic microscopes. Light striking the plate is separated into a fast ray and a slow ray and these rays vibrate in planes at right angles to each other. The preceding discussion of polarized light in strained glass applies also to light passing into the tint plate.

When the plate is placed between crossed nicols, with the vibration planes in the plate parallel to the vibration planes in the nicols, no effect is obtained and the field remains dark. However, if the tint plate is rotated, color will gradually appear, a violet color resulting when the vibration planes in the plate make angles of 45 degrees with the vibration planes of the nicols. Beyond this point rotation causes decreasing intensity of color and, at 90 degrees from the original position, darkness is again obtained. In a rotation of 360 degrees four positions of darkness are found and the plate must always be used in the 45 degree position to obtain maximum color and reproducible results with strained glass.

It is apparent from the previous discussion that the two rays of light in the tint plate produce two components in the same plane in the analyzing nicol, and that these two components interfere to give the violet color. The retardation of one ray of light over the other is generally 565 mμ, or occasionally less, depending upon the thickness. At 565 mμ, green, yellow, and orange components are practically destroyed, while the red and blue increase the intensity of the violet.

When glass of ordinary thickness is observed in a polariscope without a tint plate, strain is usually shown merely by areas of grayish white. The kind of strain is not indicated, nor is the amount of strain readily apparent. But with a tint plate, strain shows as areas of various colors which are not only a measure of the amount of strain, but also a direct indication of the kind of strain. A further advantage lies in the fact that slight variations in the amount of strain cause a noticeable change in color.

Meaning of the Colors in Strained Glass

a. Color and Thickness—As shown previously, when plane polarized light passes through strained glass it is broken up into two rays, each vibrating at right angles

to the other and with one ray traveling faster than the other. This difference in velocify leads to a condition where interference between the components of the two rays in the analyzer causes reinforcement or destruction of the light. A sensitive tint plate makes analysis of the differences in color easier and the reason for this will be explained in a later section.

However, if two pieces of the same kind of glass contain identical stress per unit area but have different thicknesses, measured in the direction in which the polarized light travels through the glass, the colors seen in the polariscope will not be the same. The thicker piece will show a color higher in the scale of Table II, if the stress is tension, or lower if the stress is compression. In a series of equally- stressed pieces of the same kind of glass, but with the thickness gradually increasing, the colors will rise or fall in the scale in a continuous order.

TABLE II

COLORS IN STRAINED GLASS

Color			*Retardation* ($m\mu$)
Tension	Yellow	Rising	325
	Yellowish green		275
	Green		200
	Bluish green		145
	Blue		115
Neutral	Violet		0
Compression	Red	Falling	25
	Orange		130
	Bright yellow		200
	Yellow		260
	White		310

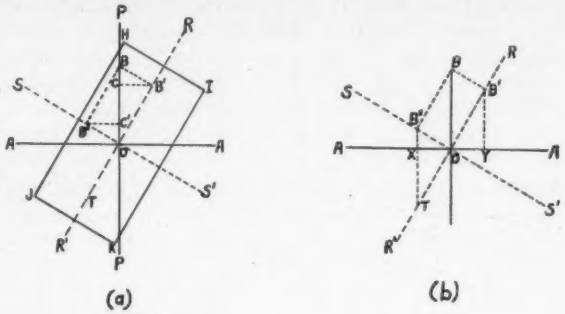
(Tint plate of 565 mμ)

The general rule may, therefore, be stated as follows: *Under constant unit stress, the retardation in strained glass, as shown by the color, is directly proportional to the thickness.* Exact measurements of the retardation must be made with the graduated quartz wedge or the Babinet compensator, each of which will be explained shortly.

b. Color and Strain—Strain is, of course, the unit deformation caused by unit stress and, although the effects seen in the polariscope are due to strain, the quantity desired is the stress. However, since the strain is proportional to the stress within the elastic limit of the glass, strain observations may be used to evaluate the stress. When a slab of glass is stretched slightly, a color will be produced in a polariscope equipped with a sensitive tint plate and, if the stretch is increased slightly, the color will rise in the scale of Table II. A further increase will produce a higher color, and this process will continue until the glass breaks. On the other hand, if the stress is compressive, the colors will fall progressively in the scale.

Fig. 17 shows the relation between strain and color for a given glass of given thickness and a chart of this kind can be drawn up for each of the various types of glass commonly used. The colors for definite stresses may be determined by actual experiment with a slab of glass. It is also possible to make up such a chart if the photoelastic constant (to be discussed later) and the retardation of the sensitive tint plate are used in conjunction with Table I.

Fig. 15. Diagrams showing why dark and light areas are produced when monochromatic polarized light is passed through strained glass.



The second rule may be stated as follows: *In a given glass of given thickness, the retardation is directly proportional to the stress in the glass.*

c. Color and the Kind of Glass—If a rod of lead glass is stretched so that the resultant tension is R pounds per square inch, a definite color is obtained in the polariscope; but if a rod of borosilicate glass is stretched to the same resultant stress, the color will not be the same. Furthermore, if a rod of lime glass is used, still another color will be obtained. Thus it can be seen that, for a given stress and a given thickness, the color obtained will be different for different kinds of glasses. This will be made clearer in the discussion of the photoelastic constant.

d. Color and the Retardation (Tint) Plate—Sometimes there is another factor that must be considered. It may happen that a piece of glass with a certain stress and a certain thickness will show different colors in different polariscopes, this being caused by a difference in the retardation, i.e., the thickness, of the sensitive tint plates used in the different polariscopes. The shades of color will not differ greatly when the variation in the tint plates is no more than 5 mμ, but the difference will be noticeable when the variation reaches as much as 15 mμ. A tint plate of 565 mμ is generally used, but some are occasionally cut with other values. In any event, the retardation can always be measured by means of a graduated quartz wedge or a Babinet compensator.

e. Color and Orientation—Orientation may refer to

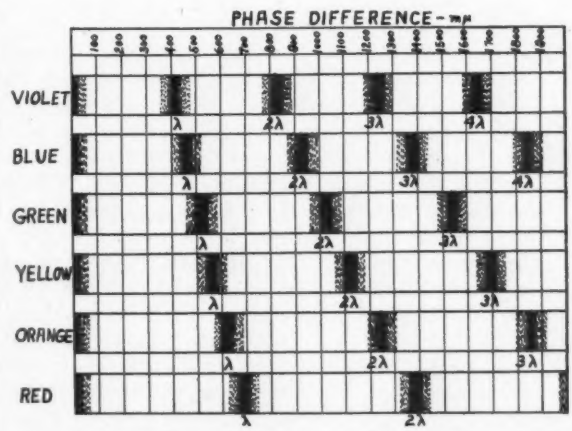


Fig. 16. Interference colors and dark bands with white light.

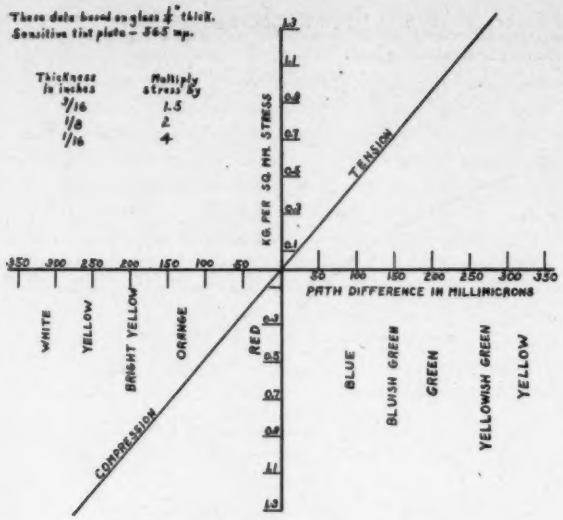


Fig. 17. Chart showing the relation between color and amount of strain in glass of a given thickness.

either of two arrangements of the strained glass in the polariscope, but one of these can be eliminated by stipulating that, in an ordinary polariscope, the glass must be held so that the direction of stress makes an angle of 45 degrees with the directions of vibration of the polarizer and analyzer. All discussions of color so far given are on this basis.

There is, however, another orientation effect. In the case of tension in the strained glass of Fig. 12, the ray vibrating parallel to the direction of the applied force is the slow ray and travels with less velocity than the ray vibrating normal to the direction of the applied force. The sensitive tint plate, just like the strained glass, also has a slow ray and a fast ray. As shown in Fig. 18, when the vibration plane of the slow ray SS in the glass is parallel to the vibration plane of the slow ray ZZ in the tint plate, the colors rise with increased stress, as indicated in Table II for tension. If the strained glass is then rotated 90 degrees, the slow ray SS in the glass will be perpendicular to the slow ray ZZ in the tint plate and, consequently, the colors fall in the order shown in Table II for compression. In the case of glass in compression, however, the slow ray in the glass vibrates in a plane perpendicular to the direction of the applied force. Therefore, if this compressed piece of glass is placed in a polariscope, with the tint plate in the position just described for the case of glass in tension as shown at the lower left in Fig. 18, the colors will fall in accordance with the compression scale of Table II as the stress is increased. If the glass is then rotated through 90 degrees, the colors will rise as shown by the tension scale of Table II.

The plane of vibration of the slow ray in the tint plate in the polariscope may be determined very easily. When the slow ray in the tint plate is parallel to the length of a rod of strain-free glass, held in the polariscope with its long direction making an angle of 45 degrees with the vibration planes of the polarizer and analyzer, the colors will rise, that is, change to blue, green, yellow, as in Table II, when the rod is pulled. But if the colors fall through, red, orange, yellow, white, as in Table II, the plane of vibration of the slow ray in the tint plate must be perpendicular to the length of the rod. Fig. 18 makes this clear.

Photoelastic Constant and the General Stress Equation

In the discussion of the meaning of the colors produced by strained glass in the polariscope several variables were mentioned. There were:

1. Thickness of the glass
2. Magnitude of the stress
3. The kind of glass
4. The retardation

From these variables it is evident that an equation can be set up showing the interrelationship of the factors. If we call the retardation R, the thickness d, the stress s, and a proportionality constant C, the equation is

$$R = Cds$$

By transformation

$$s = \frac{R}{Cd}$$

Thus, knowing the retardation, the thickness, and the value of C, the stress can be computed.

The constant C requires more attention. The third variable listed above is "the kind of glass" and the constant C expresses this factor in the stress equation. In general, C will be different for every kind of glass and is called the *photoelastic constant* of the glass. If s is in pounds per square inch, d in inches, R, in millimicrons

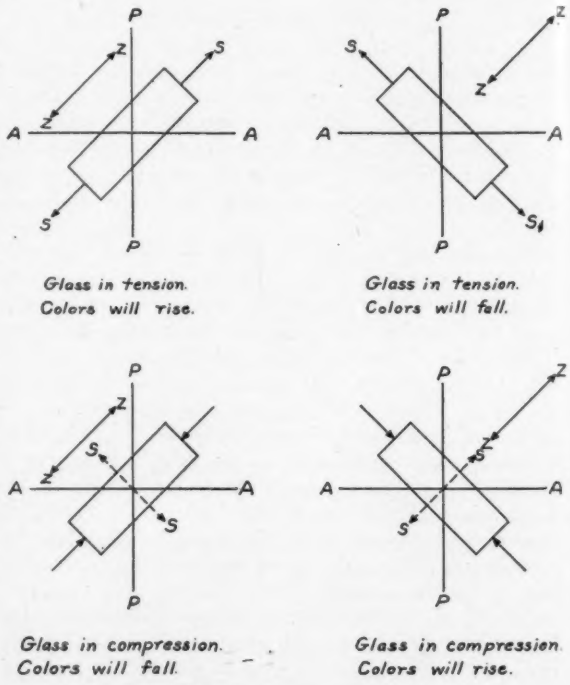


Fig. 18. Effects produced by different orientation of the sample.

($m\mu$), then the unit of C is called the *brewster*, and the stress-optical equation is written

$$R = 0.1752\ Cds,$$

where 0.1752 is a conversion factor to account for the change from metric to English units. In Table III the photoelastic constants for several glasses are given.

TABLE III*

PHOTOELASTIC CONSTANTS OF GLASSES

Glass	*Photoelastic Constant (in brewsters)*	
Corning G-5 (lead)	2.91	(1)
Corning G-8 (lime)	2.52	(1)
Corning G-6	2.74	(1)
Corning 705AJ	3.68	(1)
Corning G-71	3.36	(1)
Corning 705AO	3.64	(1)
Corning 702P (Nonex)	3.36	(1)
Corning 702EJ (Pyrex)	3.65	(1)
Corning G-371BN (Uranium)	3.54	(1)
Borosilicate crown	2.91	(2)
Ordinary crown	2.62	(2)
Light barium crown	2.87	(2)
Heavy barium crown	2.19	(2)
Barium flint	3.16	(2)
Light flint	3.26	(2)
Medium flint	3.19	(2)
Heavy flint	2.72	(2)
Extra heavy flint	1.24	(2)
Jena 0-152 (16% lead)	2.78	(3)
Jena 0-154 (31% lead)	2.94	(3)
Jena 0-103 (47% lead)	2.89	(3)
Jena 0-192 (56% lead)	2.26	(3)
Jena 0-41 (63% lead)	1.77	(3)
Plate glass	2.63	(3)

(1) Computed from A. W. Hull and E. E. Burger, *Physics*, 5, 384 (1934).

(2) Computed from L. H. Adams and E. D. Williamson, *J. Franklin Inst.*, 190, 597 (1920).

(3) Computed from L. N. G. Filon, *Cambridge Phil. Soc. Proc.*, 11, 478 (1900-1902); 12, 55, 313 (1902-1904).

*Comparison of the values in Table III computed from the measurements of Adams and Williamson are not in agreement with those given as B in Table XVI 29, page 428, of G. W. Morey's book "The Properties of Glass," Reinhold Publishing Corporation, N. Y., 1938. Dr. Morey has been able to discover a slight error in his conversion factor, and has kindly supplied the following corrected values for B in his table (reading from top to bottom): 2.91, 2.62, 3.26, 2.87, 3.16, 2.19, 3.19, 2.72, 1.24, 3.86, 2.99, 2.66, 1.41, +1.96, 4.41, 2.83. The constants in both tables are thus brought into agreement. A slight discrepancy occurs in the values for glasses 0-152, 0-154, 0-103, and 0-41, as given in Dr. Morey's Table XVI 30A, page 429, and the values given above in Table III.

Three rules for conversion of units are worth knowing. These are: (1) To change from brewsters to millimicrons retardation per pound per square inch stress per inch thickness multiply by 0.1752; (2) to change from brewsters to millimicrons retardation per kilogram per square centimeter stress per centimeter thickness divide by 1.0197; and (3) to change from millimicrons per kilogram per square centimeter per centimeter thickness to millimicrons per pound per square inch per inch thickness multiply by 0.1788.

The photoelastic constant, sometimes called the stress-optical co-efficient, is determined by loading a specimen of glass of given thickness to a definite stress and then measuring the retardation. The values of C will vary slightly with the wave-length of the light used.

Estimation of Stress from Color

This method is not one of extreme accuracy, but it is a very useful one for rapid and approximate estimations of stress in the factory. Use is made of the general stress equation given above and an example will make the method clear.

First assume a sensitive tint plate with a retardation of 565 $m\mu$, in which case the colors and retardations given in Table II can be used, and suppose that a sample of 702P glass one-quarter inch thick is stretched. The value of C will be 3.36 brewsters (Table III). Suppose the color seen in the polariscope is a yellowish green, corresponding to a retardation of 275 $m\mu$ (Table II). Thus R equals 275, C equals 3.36, and d equals 0.25. As we know, $R = 0.1752\ Cds$, and

$$s = \frac{R}{0.1752\ Cd}$$

Then,

$$s = \frac{275}{0.1752 \times 3.36 \times 0.25} = 1870$$

The stress is 1,870 pounds per square inch tension.

If the glass is compressed, and a yellow color is obtained the retardation is 260 $m\mu$ (see Table II), and the stress is 1,760 pounds per square inch compression.

This method should be used only for approximate stress values. Where great accuracy is necessary or desirable the graduated quartz wedge or the Babinet compensator should be used and the use of these devices will be explained in the next article of this series.

(*To be continued in the June, 1939, issue of* THE GLASS INDUSTRY.)

G. C. A. WILL MEET MAY 23-24

The Glass Container Association reports that its annual meeting will be held at the Greenbrier Hotel, White Sulphur Springs, on Tuesday and Wednesday, May 23rd and 24th. While the program has not finally been determined, the schedule of meetings will be arranged as in the past. The general sessions will be held on the morning of the 23rd and followed by a golf tournament in the afternoon and a dinner in the evening. The Glass Division meeting will be held on the morning of the 24th. Reservations should be made directly with the Greenbrier. These dates were deliberately selected with the idea that many glass men might take advantage of them to enjoy the preceding week-end in White Sulphur.

WALTER B. SWINDELL, Jr., 1880-1939

It is with regret that THE GLASS INDUSTRY records the death of Walter B. Swindell, Jr., president of Swindell Brothers, Inc., bottle manufacturers, who died suddenly on April 6th at the age of 59. He was closely associated with the glass industry for many years and is survived by his widow and a son and daughter by his first marriage.

CHANGES IN SWINDELL ORGANIZATION

The following changes have been announced by Swindell Brothers, Inc., of Baltimore: John J. Jeffries, executive vice-president, has been placed in charge of the general management of the business. Joseph B. Scott, sales manager, will move from New York City to the home office in Baltimore, where he will continue to serve as general sales manager.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_710H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.032
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 - .0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite (Na_3AlF_6) Natural Greenland (Kryolith)	lb.	.0865	.0925
Synthetic (Artificial)	lb.	.0825	.0875
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	28.00	....
In bags	ton	29.60	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0725	....
In 5 Ton lots	lb.	....	.0775
Less than 5 Tons	lb.	....	.0825
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	8.50	8.50
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	9.00
Burnt, ground, in 180 lb. drums	Per drum	1.60	1.70
Kiln Dried ($CaCO_3$) 10x30 mesh	ton	1.75	....
Kiln Dried ($CaCO_3$) 16x120 mesh	ton	1.75	....
Nepheline Syenite, f. o. b. shipping point	ton	13.00-14.00	....
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.029	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.07
Antimony oxide (Sb_2O_3)	lb.	.11	.11¾
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Pyrophyllite, (20% Al_2O_3)	ton	9.00	12.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.035-.04	.04¼-.05
Tin Oxide (SnO_2) in bbls	lb.	....	.50
Titanium Oxide (ceramic grade)			
In bags	lb.	.12¼	.12½-.13
In barrels	lb.	.12½	.12¾-.13¼
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .01¼-.01½ higher)		.0225	.0235

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	.70-.75
Chromite (99% through 200 mesh)	ton	35.50	40.00
Chromite ore (air floated)	ton	55.00	58.00-73.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls. 350 lbs. or more,	lb.	....	1.67
Less than 350 lbs.,	lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.165
Black (CuO)	lb.	....	.16-.17
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425-.09
Black (Fe_3O_4)	lb.	.04½	.09
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls	lb.	....	.145
Manganese, Black Oxide			
In Paper bags	ton	47.50	50.50-54.50
In Burlap bags	ton	49.25	51.75-56.75
In Casks	ton	51.50	54.00-59.00
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.08¾	.09-.09¼
Powdered	lb.	....	.09¼-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.17-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08¼	.08¾-.08¾
Sodium selenite (Na_2SeO_3)	lb.	....	1.50-1.65
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.75-1.80
Yellow	lb.	....	1.75-1.80
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_3) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.65-2.75
Yellow orange	lb.	....	1.75-1.80

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.063	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¾
Putty Powder	lb.	....	.38-.42
Rotten Stone, (Domestic)	lb.	....	.02
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

EQUIPMENT AND SUPPLIES

NEW APPLIED COLOR PROCESS

Adaptation of china decorating processes employing decalcomania transfers to the glass container field is announced by L. S. Green, president of the Universal Ceramics Corporation, New York. The result is a type of ceramic color label which is fused in the glass surface, and is reported to permit considerably more latitude in super-imposition of colors and fineness of detail than other known methods.

Mr. Green points out that the process is designed for application in the plant of the glass manufacturer and the use of modern decorating lehrs. Any number of colors in the same area may be applied at the same time, in any lithographic design and thoroughly fused in one firing cycle. This permits the duplication in glass of existing labels and trade-marks. Any size or shape of label may be reproduced, it is said.

The ceramic colors are applied to decalcomania paper by usual lithographic methods. In the glass plant, transfer to the container is done by hand, but could be accomplished by machine. The decorated ware is then placed in the lehr. Alkali resistant colors can be offered to those manufacturers whose bottles will be subject to washing solutions. It is claimed that the fusion of color will be found by test to enhance considerably the ability of the decorated surface to withstand both abrasive and corrosive action.

Mr. Green states that Universal Ceramics Corporation is in a position to offer a complete range of colors, including supplementary shades. Since the Pyrocolor decalcomania can apply any number of colors, it becomes a labeling device in the hands of the bottle manufacturer. This is not to say that its cost can be comparable to paper labeling. However, glass containers capable of making a number of trips and today identified with well-established multi-colored labels or trademarks, may be well adapted to a process of this nature.

NEW LOBBY IN GLASS

The Columbia Alkali Corporation, Barberton, Ohio, are utilizing several forms of structural glass in the new lobby of their office building. The walls are covered with gray carrara glass trimmed in maroon red carrara, manufactured by Pittsburgh Plate Glass Co. The ceiling is painted with Pittsburgh Plate Wall-Hide interior paint. The glass blocks utilized were produced by the Pittsburgh Corning Corporation, and prove very effective in permitting plenty of light to enter into the lobby. The company inscription is etched on a separate piece of glass and placed against a large mirror which is exactly opposite the front doors. The mirror and the entire lobby are lighted by indirect lighting which can be regulated to give any amount of light desired.

NEW REEVES HYDRAULIC AUTOMATIC CONTROL

Reeves Pulley Co., Columbus, Ind., announces a new and improved type of hydraulic automatic control for use with the Reeves Variable Speed Transmission. This control provides entirely automatic speed regulation to make possible synchronization of different machines and separate sections of a single machine; maintenance of constant tension and uniform peripheral winding speeds; and maintenance of uniform pressure, weight, liquid level, temperature and other variable elements.

The control is simple and compact in design, with few working parts, sensitive and positive in speed regulation and dependable and economical in performance. Pressure of only two or three ounces will produce change in speed. Back lash and lost motion are definitely eliminated and liquid in the oil pump acts as a brake to prevent movement when the control is in "neutral," thus preventing "coasting" and "hunting."

From 6 to 20 seconds are required to shift the Transmission from maximum to minimum speed and vice versa, depending on size and ratio. Protective mechanism absorbs the shock of sudden or violent shifting, thus preventing damage to control or Transmission.

The control is mounted at one end of the Transmission frame. A self-contained hydraulic power plant is mounted on the right hand set of shifting levers of the Transmission (which control disc and belt diameters and thus effect speed changes). This plant consists of a small electric motor operating an oil pump in a reservoir to supply hydraulic power.

A two-way valve is mounted integral with a cylinder immediately above the reservoir. A piston connects to the left hand set of shifting levers while the cylinder connects to the right hand set, the combination of which, together with motor and oil pump, offers the source of power for speed regulation. The valve directs flow of oil to either right or left hand side of the piston, thus operating it in either direction to increase or decrease Transmission speeds.

Equalizing links interposed between the two pairs of shifting levers insure equal movement on both pairs and maintain perfect alignment of the Transmission V-belt in the discs. The valve is actuated by a connecting rod which connects to an extended lever, above. This lever may be attached by cable or chain, or direct, to a compensating or floating roll, pressure regulator, moving carriage or part of the driven machine from which indication of required speeds can be taken.

The control lever can be located any place on a 360° circle to give direct connection to the operating mechanism by the means described above.

EAGLE-PICHER DEVELOPS LEAD SILICATE

Announcement of the development of a new product—Eagle lead silicate—has been made by the Eagle-Picher Sales Co., Cincinnati.

This latest Eagle-Picher contribution to ceramic processing is described as a glassy-like, fritted material which is a chemically combined lead-silicate, containing approximately 85 per cent PbO and 15 per cent SiO_2. It is composed of fairly fine particles, yet is said to be remarkably dustless. Its melting temperature is 725°-775°C.

Rigorous tests are reported to prove that Eagle lead silicate has many important features and technical advantages in the ceramic industry. Numerous direct benefits are prophesied for its use in the manufacture of raw glazes, glass batches and enamels. Eagle lead silicate is now being marketed in 100-lb. paper bags.

NEW OFFICES FOR WISSCO

After 17 years at 41 East 42nd St., New York City, the Wickwire Spencer Steel Company and its subsidiary, the American Wire Fabrics Corporation, announce the removal as of May 1st, 1939, of their combined General Offices and Eastern District Sales Offices to 500 Fifth Ave., New York City. This removal to larger quarters, occupying the 25th floor of the building at the northwest corner of 5th Ave. and 42nd St., is consistent with radical plant modernization now nearing completion.

NEW CASTABLE REFRACTORY

As a result of its recent development work on castable refractories, Johns-Manville announces a new Light Weight Firecrete for making special refractory shapes, for replacing difficult brick construction, for lining furnace doors, and for making small monolithic linings. The new product is suitable for working temperatures up to 2200°F.

Accepted laboratory and service tests have shown that this latest addition to J-M's line of Firecrete products possesses an exceptionally low heat storage capacity. This is of especial importance in intermittently operated furnaces, since appreciable quantities of heat are wasted in heating heavy fire brick and then allowing the furnace to cool. Light Weight Firecrete has been shown to be four times as effective as fire brick in retarding heat, while having only half its weight. Also, its resistance to spalling is such that it will withstand direct exposure to flame temperatures. Sixty-five pounds of the material are required per cubic foot of finished construction. It can be used to form any required refractory shape. This is accomplished within a period of 24 hours simply by mixing Light Weight Firecrete with water and casting it into a form.

SUMMARIES OF A.C.S. PAPERS

(*Continued from page* 181)

at high temperatures will be arrested and a non-equilibrium state will be frozen which determines the properties of the product.

Glasses, in contradistinction thereto, have reached such a degree of homogeneity in the molten state that prolonged heating at these temperatures can not affect the properties materially unless the composition would change due to volatilization or as a result of refractory attack. The rate of cooling, however, is of considerable influence on the properties of the resulting glass.

In order to understand this influence of the thermal history on the properties of glass we assume that two different processes are going on in a glass when cooled. One kind responds practically instantaneously to temperature changes whereas the other requires time. The sluggish changes are due to atomic rearrangements whereas the fast changes are due to shifts in the atomic configuration in which the atoms stay in geometrically similar positions. These two phenomena are also well known in crystalline materials and the rule of Konigsberger explains rapid and sluggish changes in crystals on the same basis. For the properties of glass it is of particular interest that only the sluggish changes can be frozen in by chilling.

In order to present the properties of glass as a function of temperature and thermal history we can use a space diagram as shown in the figure. In this figure the length of a glass rod is plotted against the temperature in one plane and against the thermal history in a perpendicular plane. The thermal history is expressed by the temperature from which each sample has been chilled to room temperature. Other properties like density, electric conductivity, viscosity, and dielectric constant show a very similar behavior.

Glasses seem to remember not only the previous heat treatment but also mechanical and electrical treatment; so that we may speak of a mechanical and electric history as well. The delayed elastic processes are due partially to the previous field of mechanical forces, and the amount of electric current passing through a glass depends not only on the present voltage applied but also on the previously acting electric fields.

RUDOLPH BLASCHKA, 1857-1939

Rudolph Blaschka, creator of the amazingly accurate glass reproductions of flowers in the Harvard Museum, died on May 1st in Hosterwitz, Germany. It is reported that Rudolph and his Bohemian father, who died in 1895, were the only ones who knew the secret of making these flowers, which had been handed down for generations in this family of glass men and botanists. When asked to suggest a successor, Blaschka said, "If you will find me someone who has generations of artists working in glass behind him and who will begin to work at the age of ten years and work ten hours a day for ten years, then I could begin to teach him." But Blaschka leaves behind him a legacy of 840 species of flowering plants in glass and more than 3,500 sections and magnified details in the Harvard Museum.

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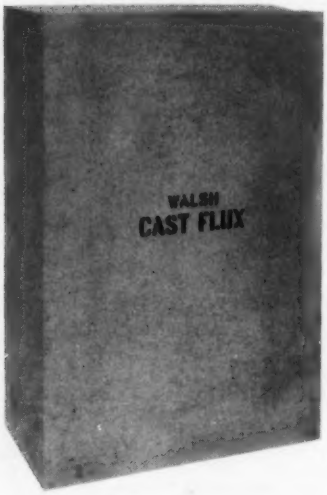

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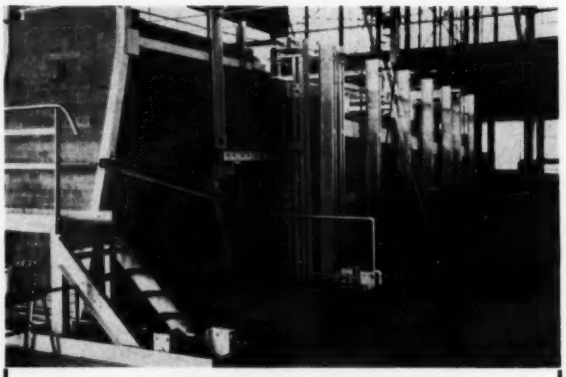

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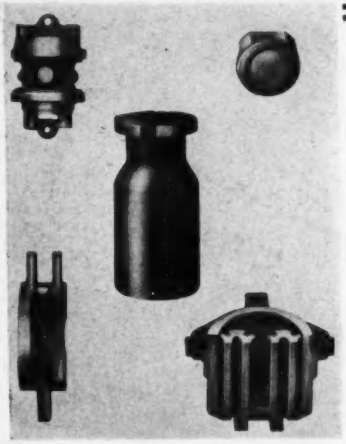

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